Vol. 17. No. 99. JANUARY, 1938. Price 2/-. [Subscription 24/- per annum post free.]

METALLURGIA

THE BRITISH JOURNAL OF METALS

669.05
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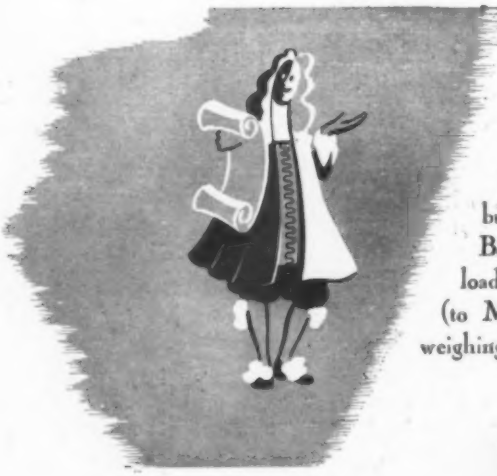
HABEAS CORPUS



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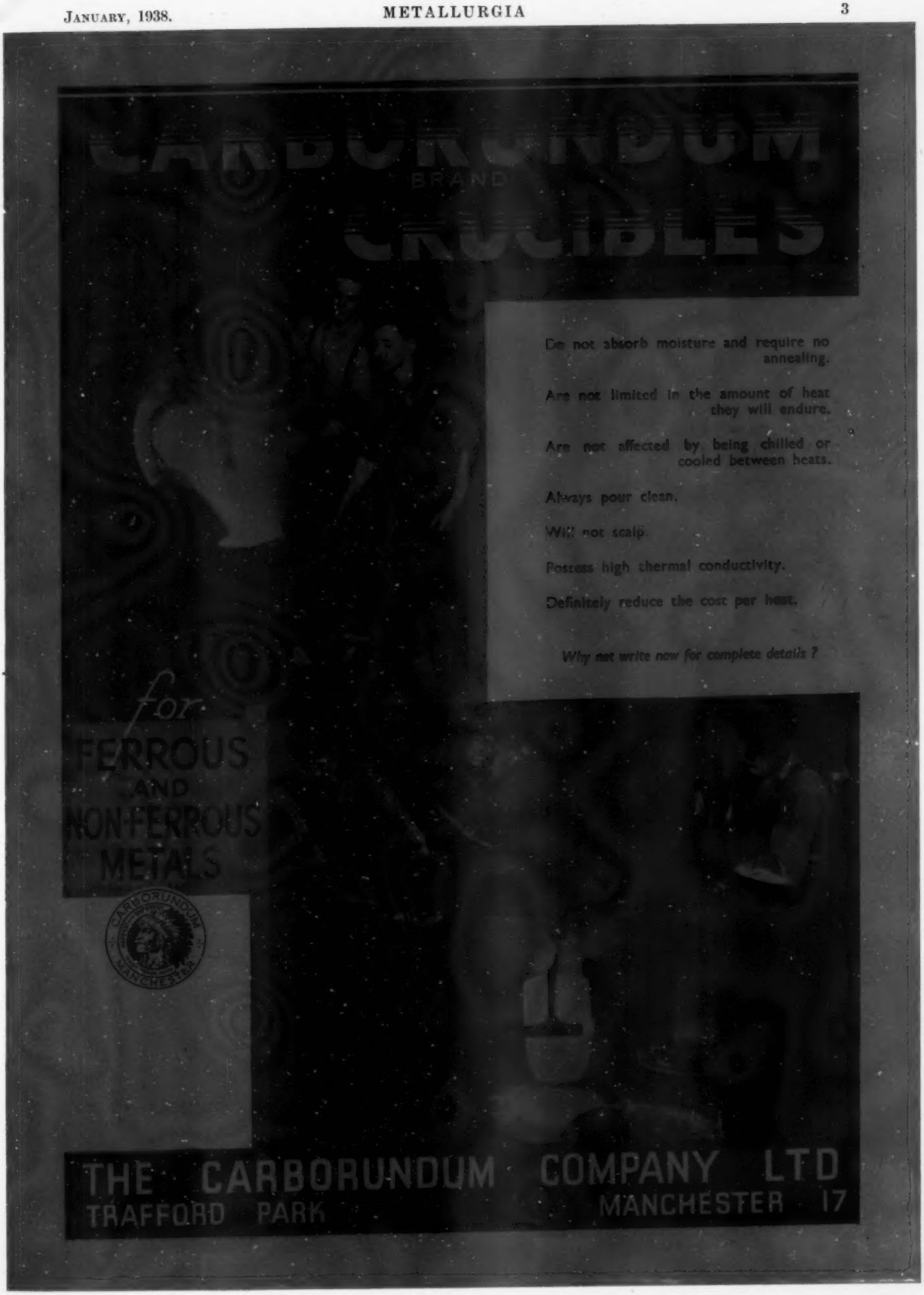
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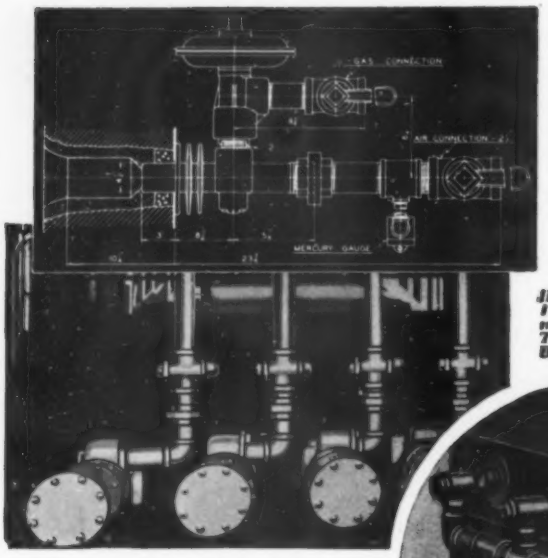

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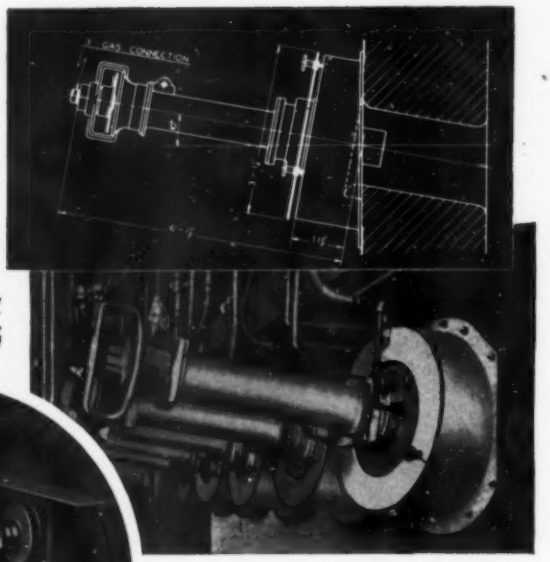
Two-Stage High Pressure Velocity Burners.



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SR Type Burner or reverberatory furnace.

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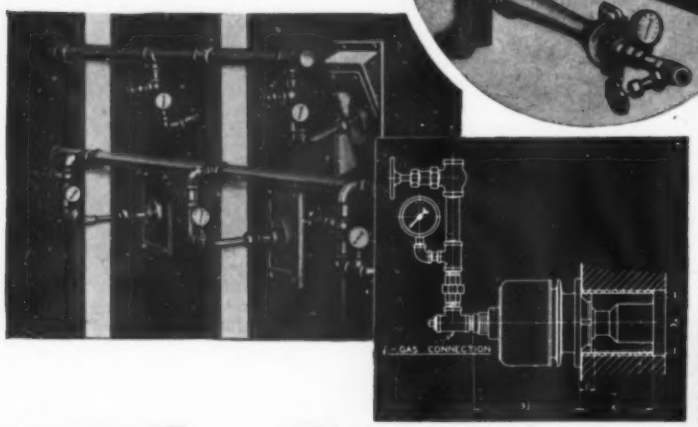

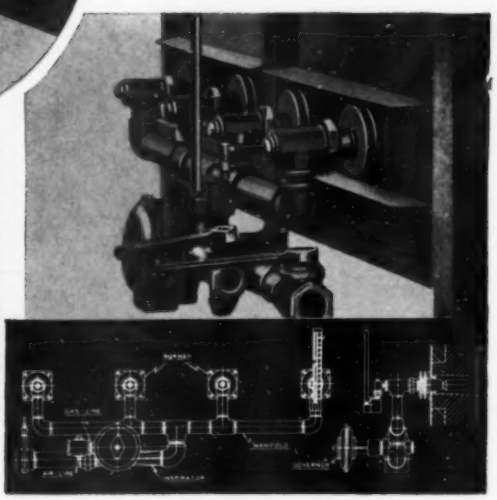

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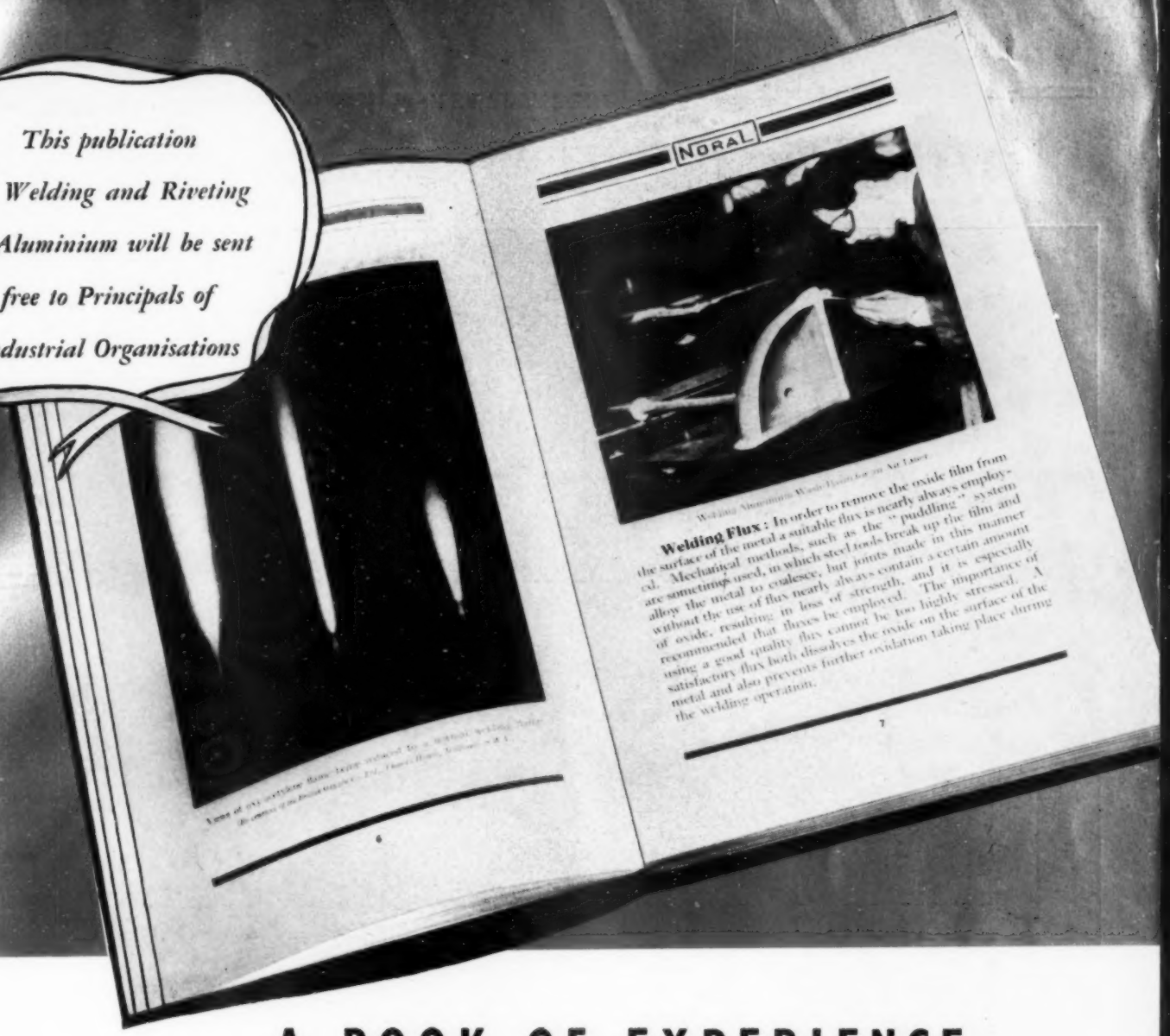
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Welding Aluminium Waste Heat Boiler for an Air Liner
Welding Flux: In order to remove the oxide film from the surface of the metal a suitable flux is nearly always employed. Mechanical methods, such as the "puddling" system are sometimes used, in which steel rods break up the film and allow the metal to coalesce, but joints made in this manner without the use of flux nearly always contain a certain amount of oxide, resulting in loss of strength, and it is especially recommended that fluxes be employed. The importance of using a good quality flux cannot be too highly stressed. A satisfactory flux both dissolves the oxide on the surface of the metal and also prevents further oxidation taking place during the welding operation.
7

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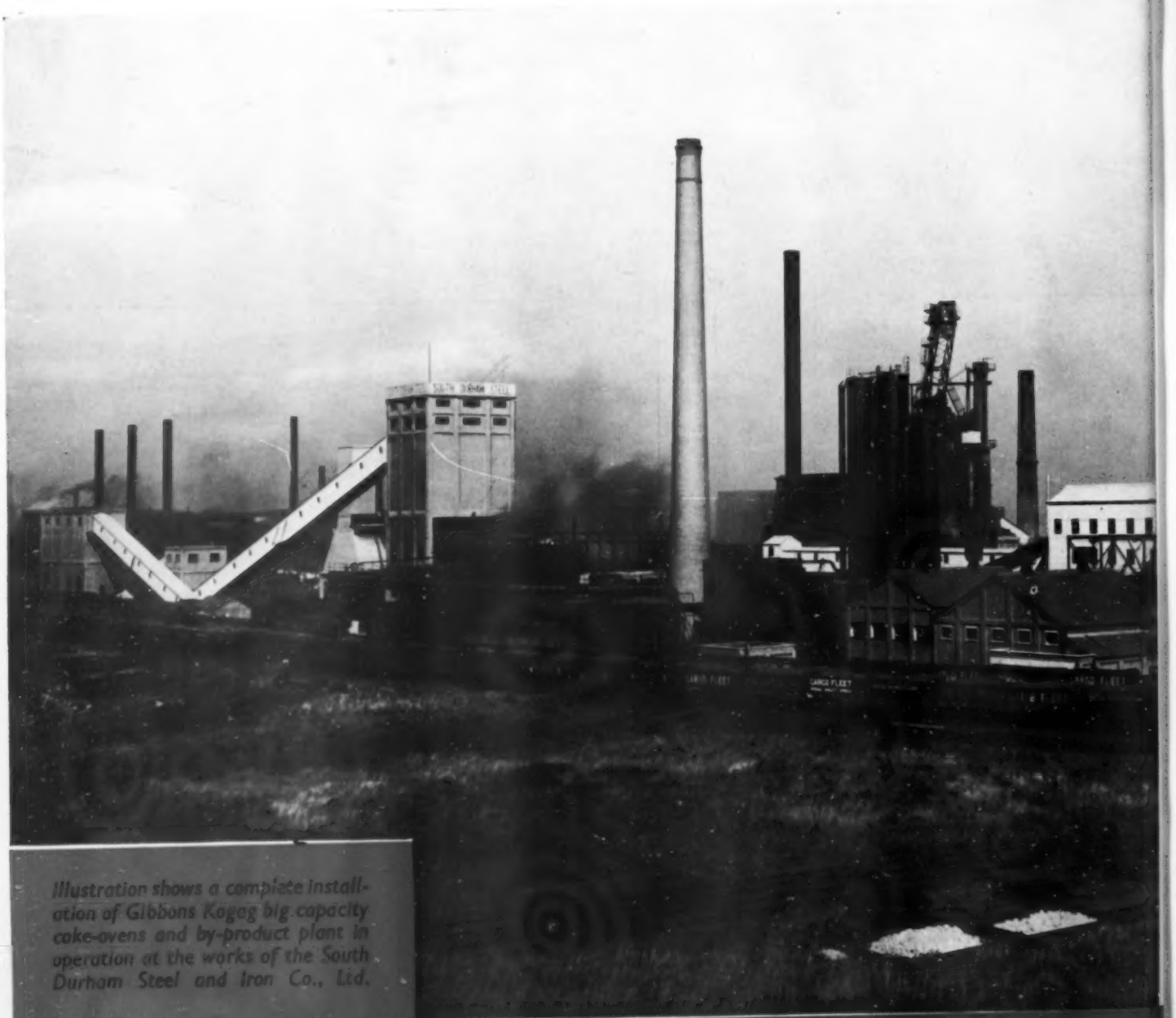

Illustration shows a complete installation of Gibbons Koppag big capacity coke-ovens and by-product plant in operation at the works of the South Durham Steel and Iron Co., Ltd.

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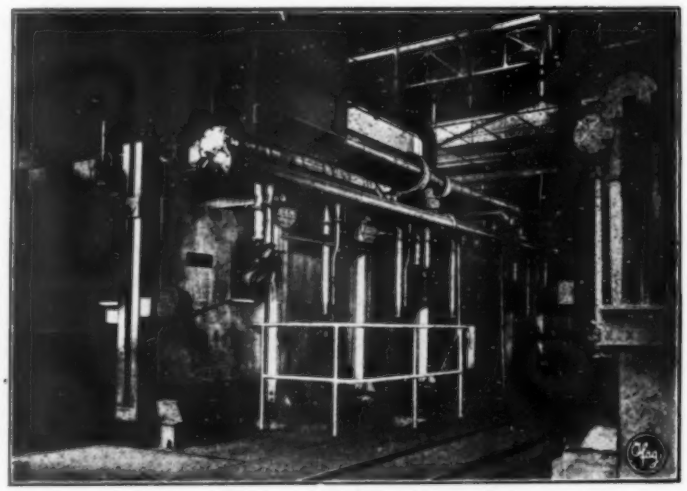

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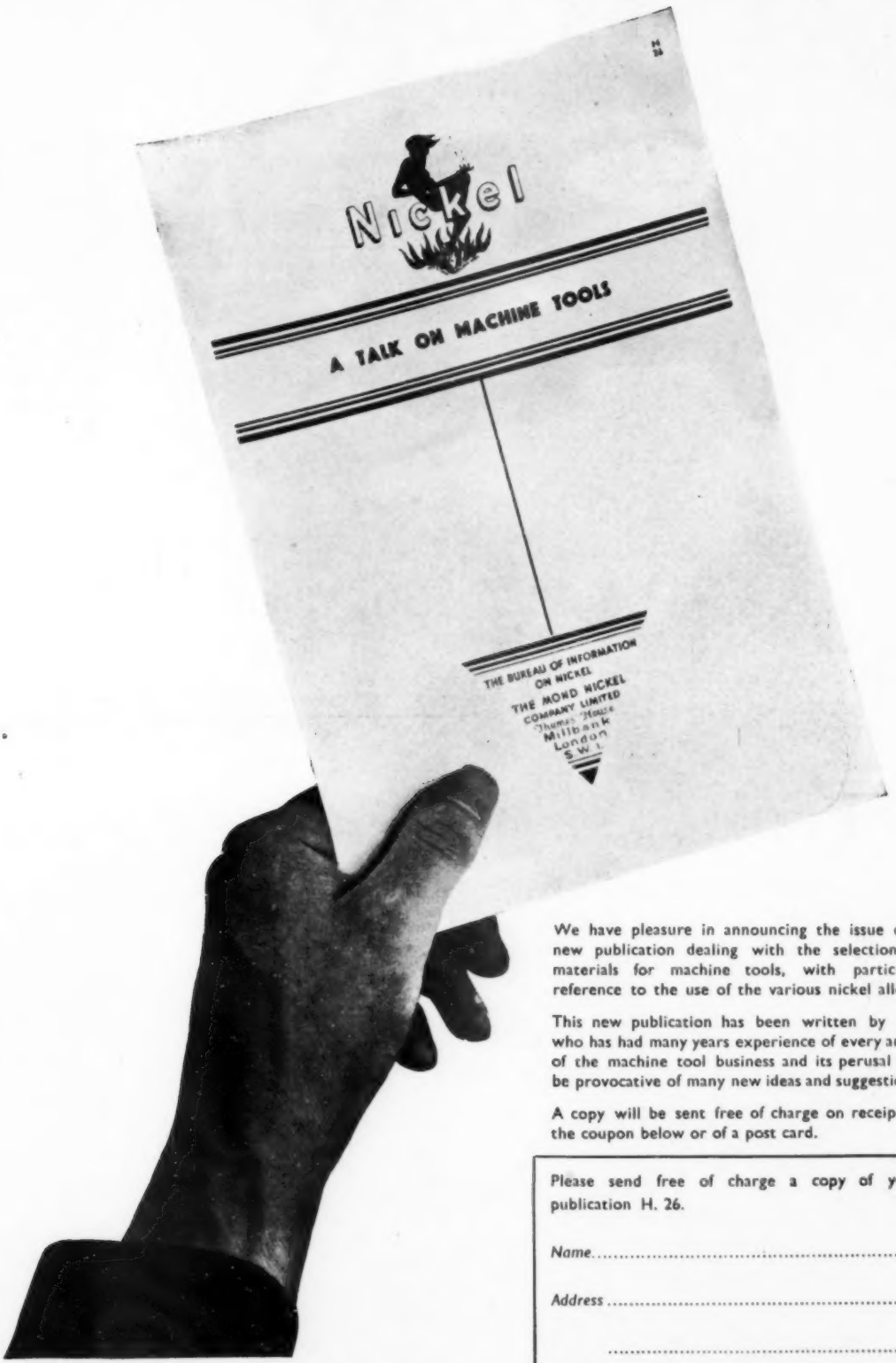

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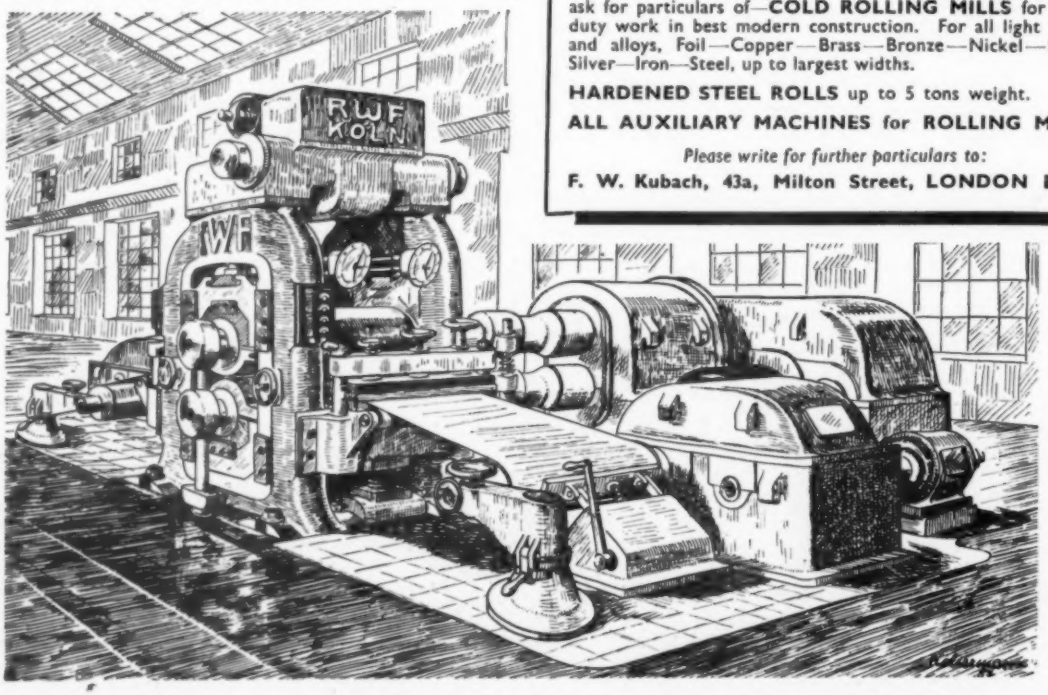

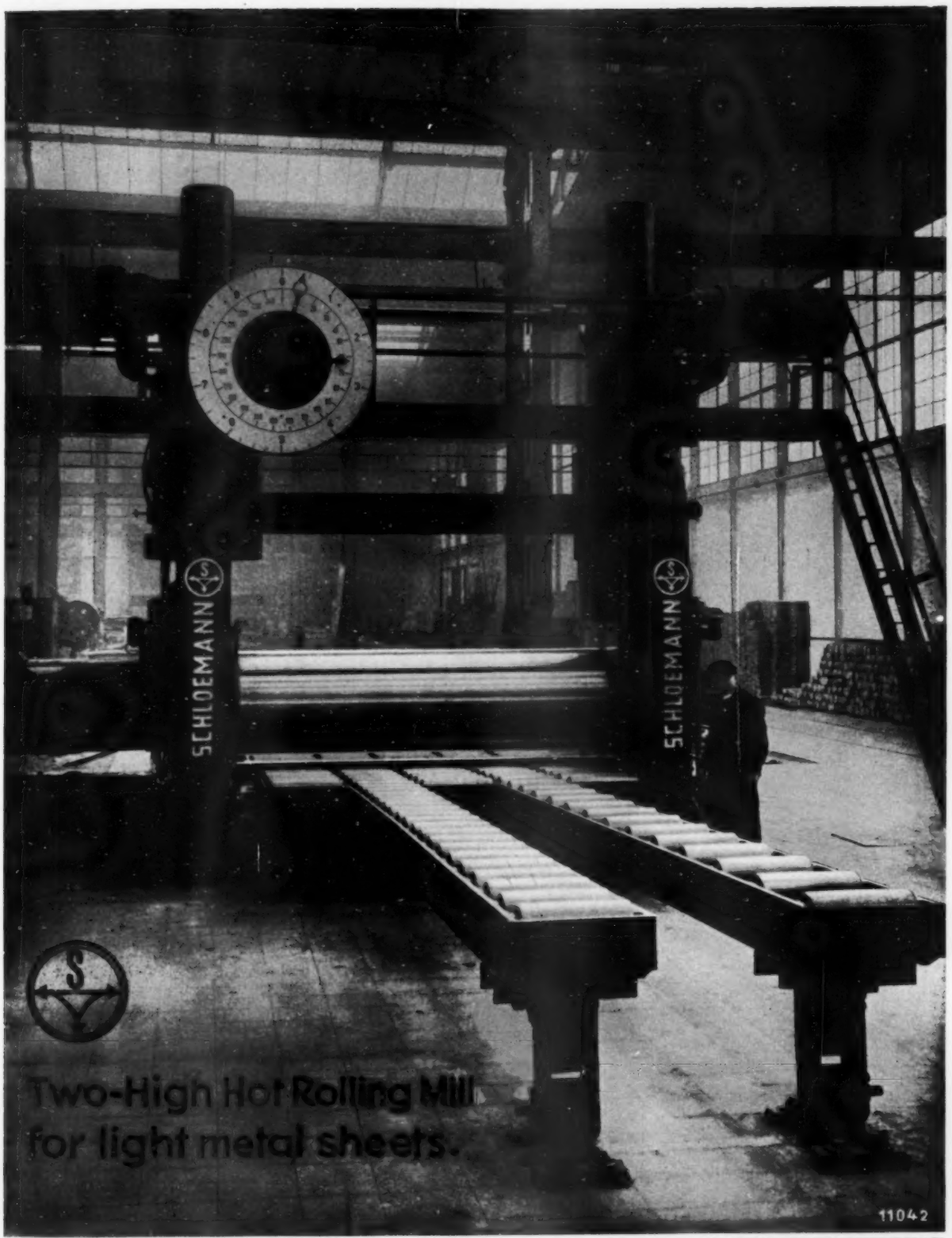

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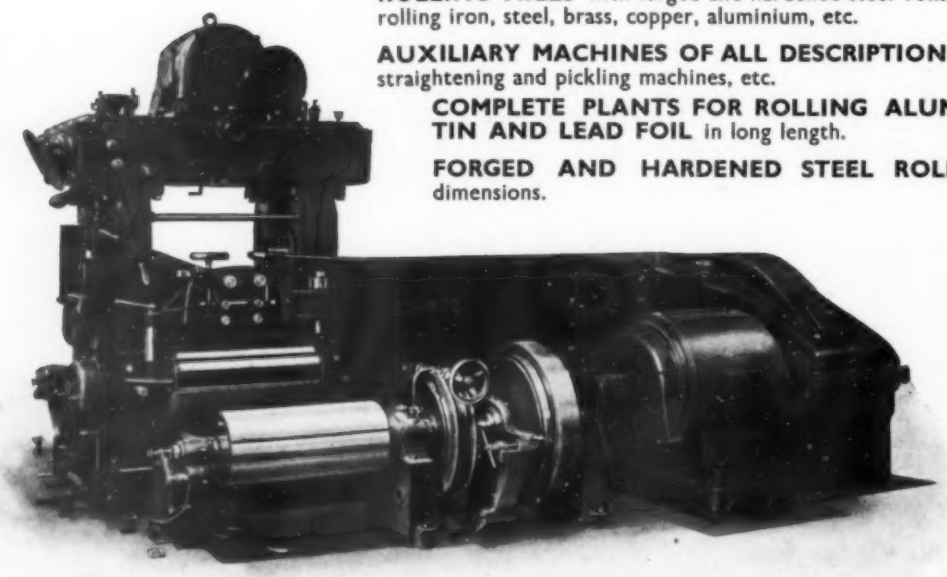

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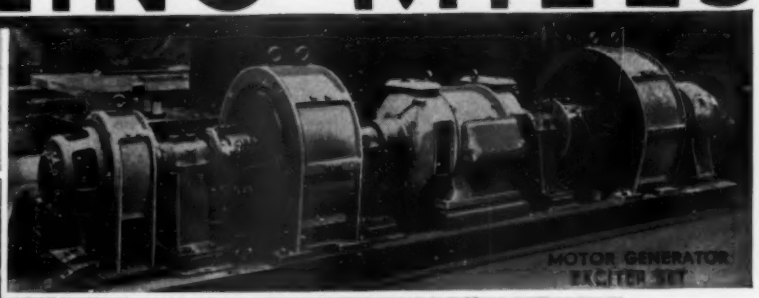

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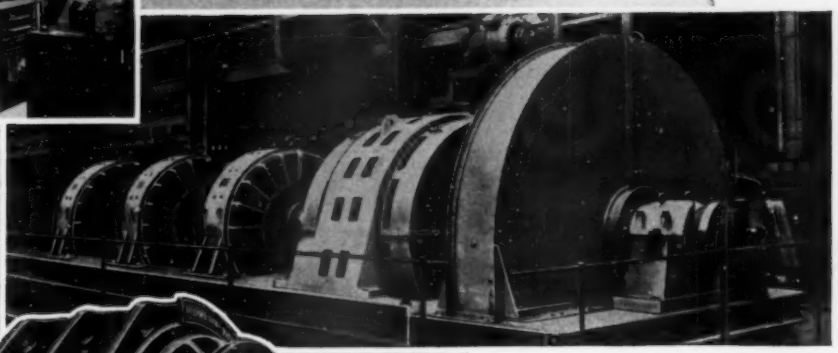
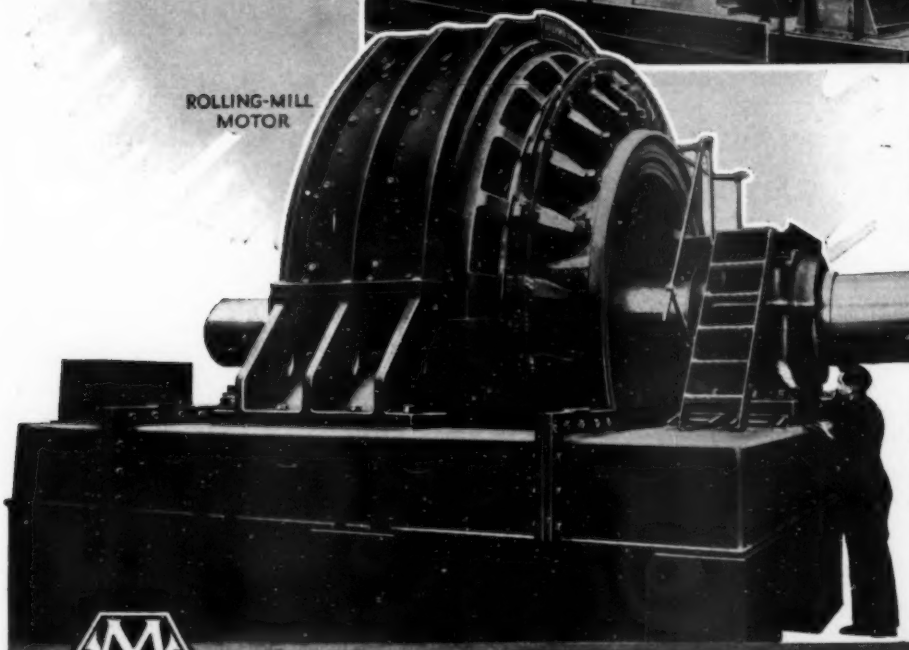


WARD-LEONARD ILGNER SET



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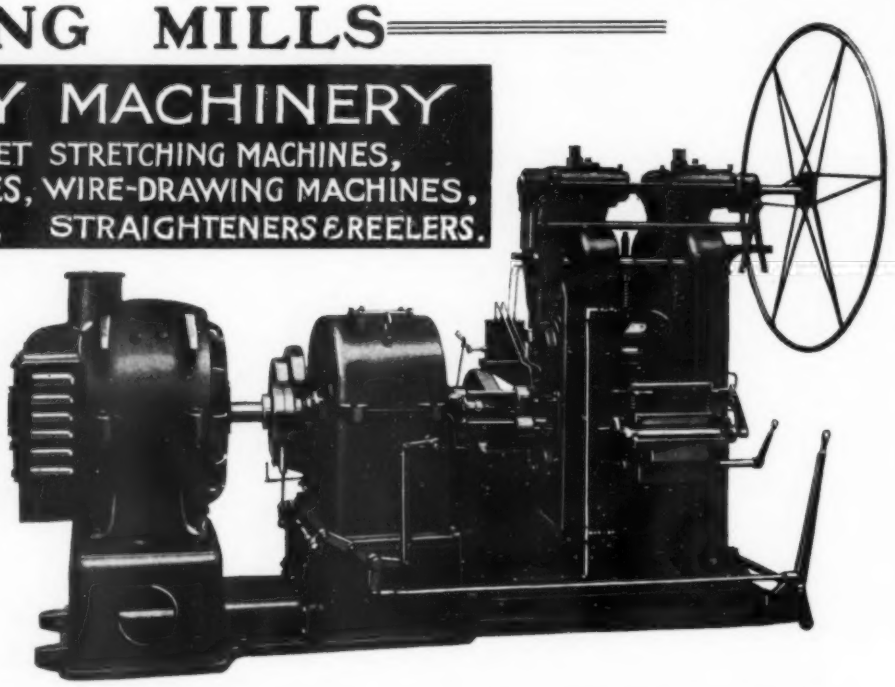

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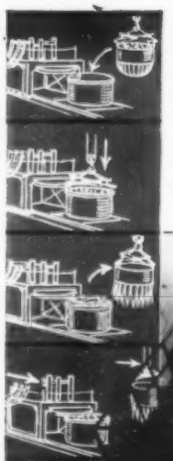

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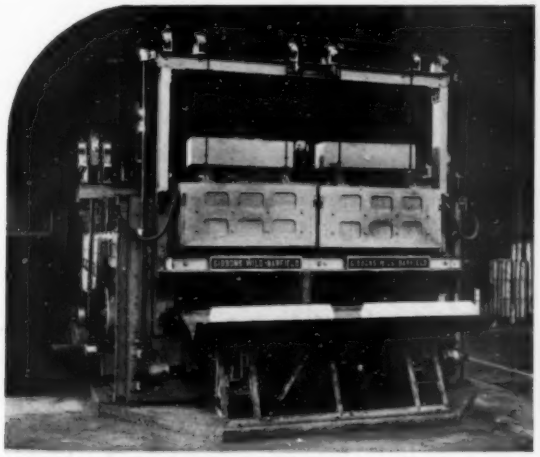

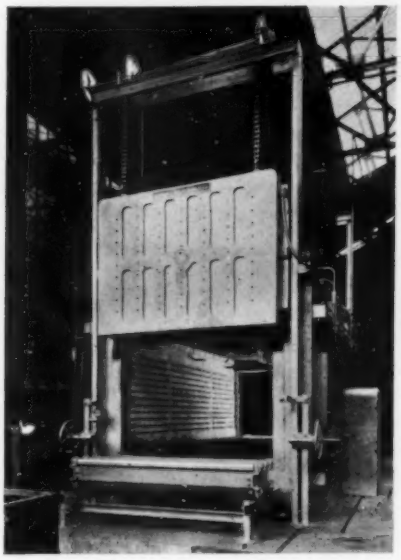

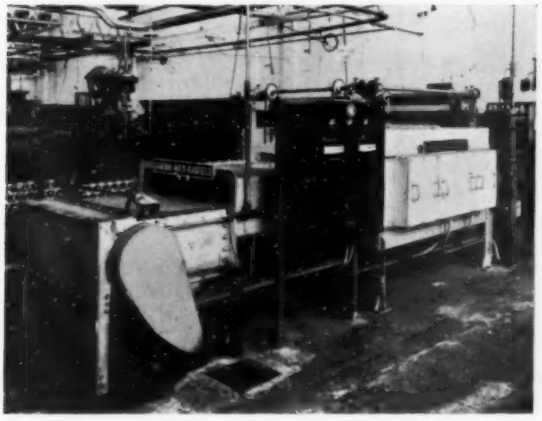

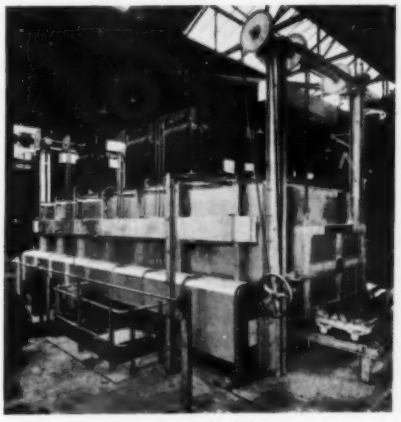

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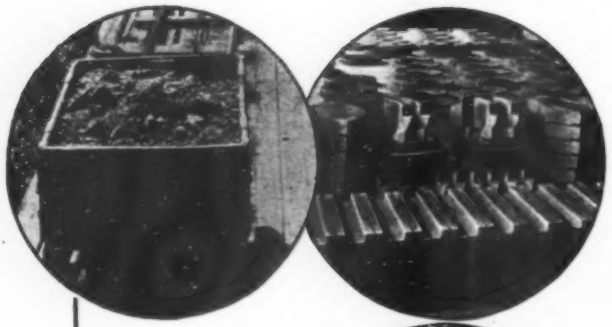

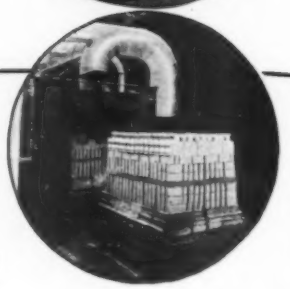

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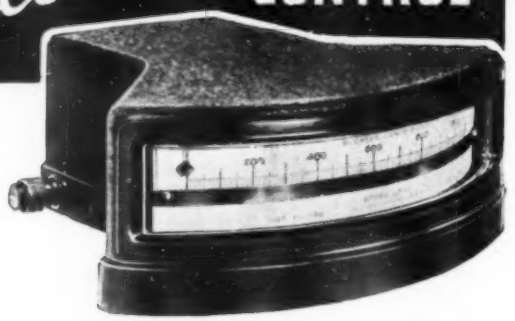

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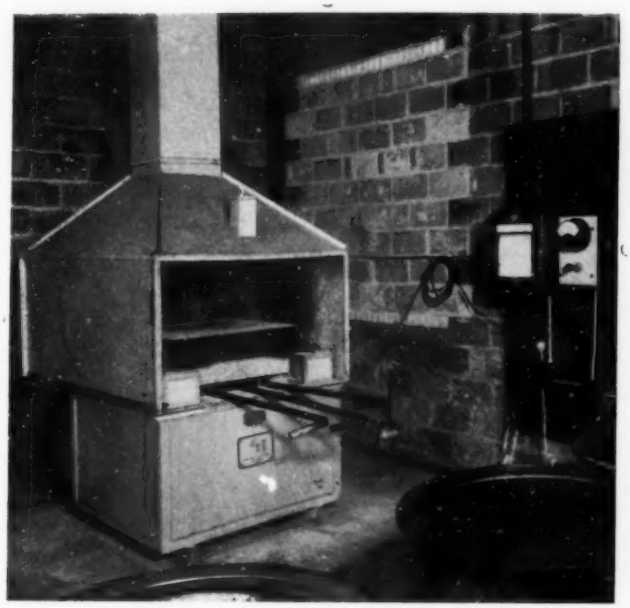

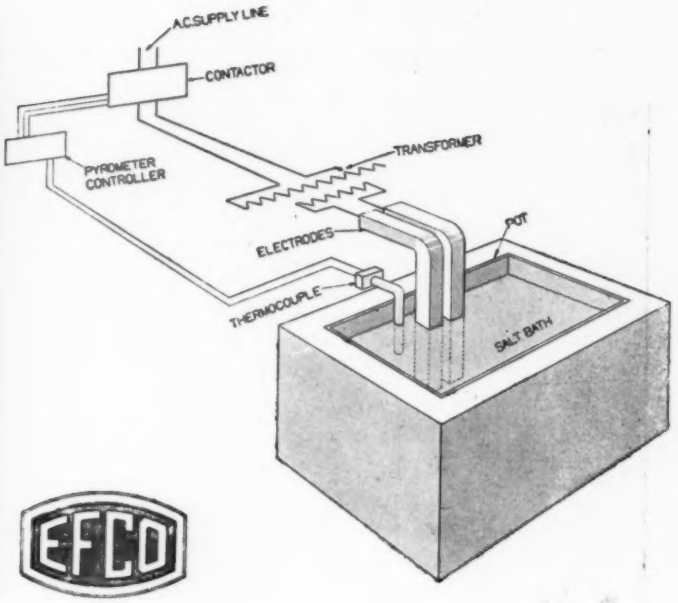

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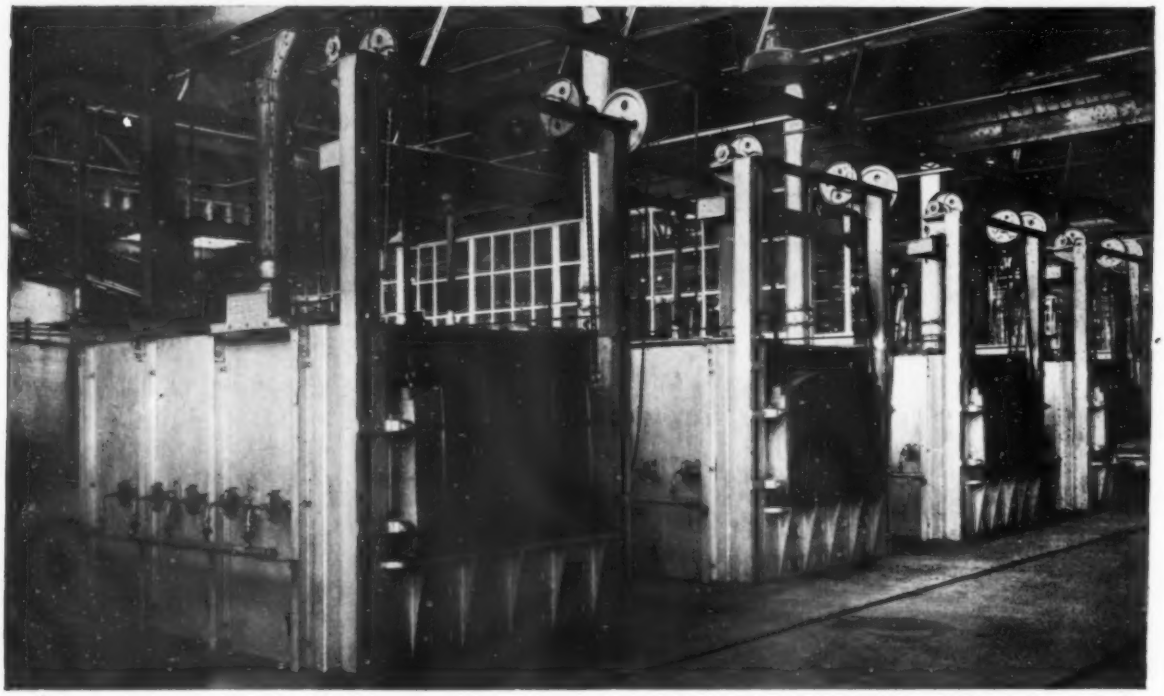

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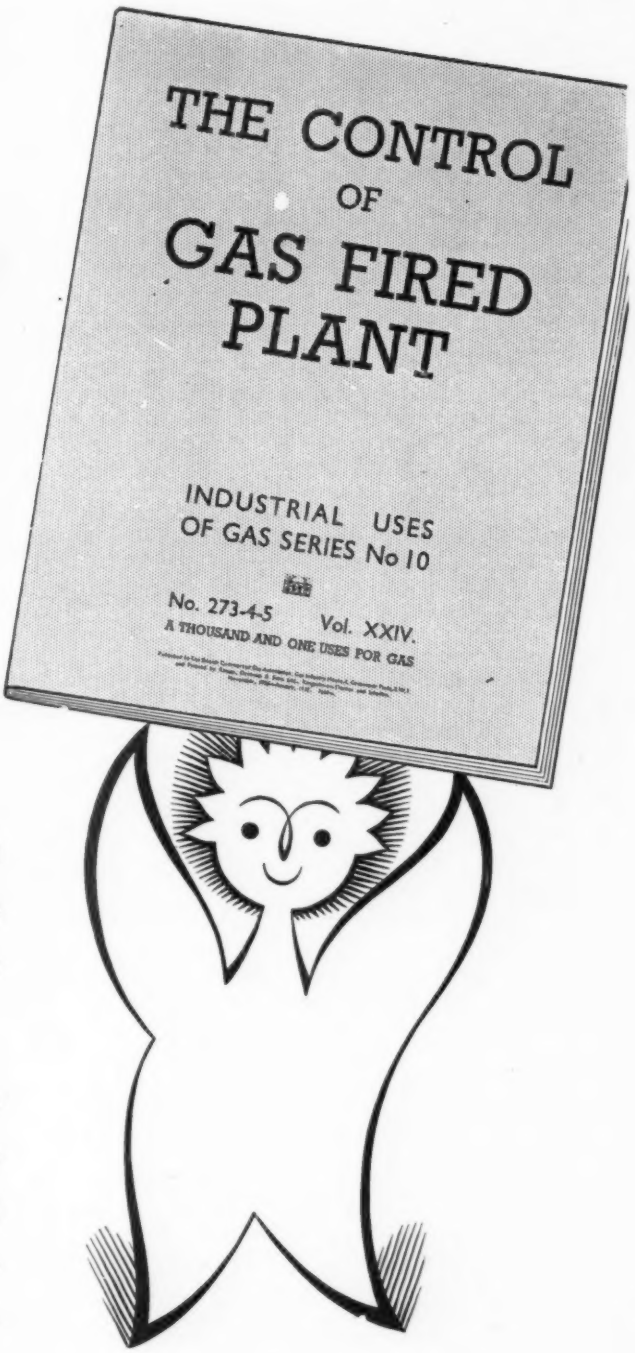

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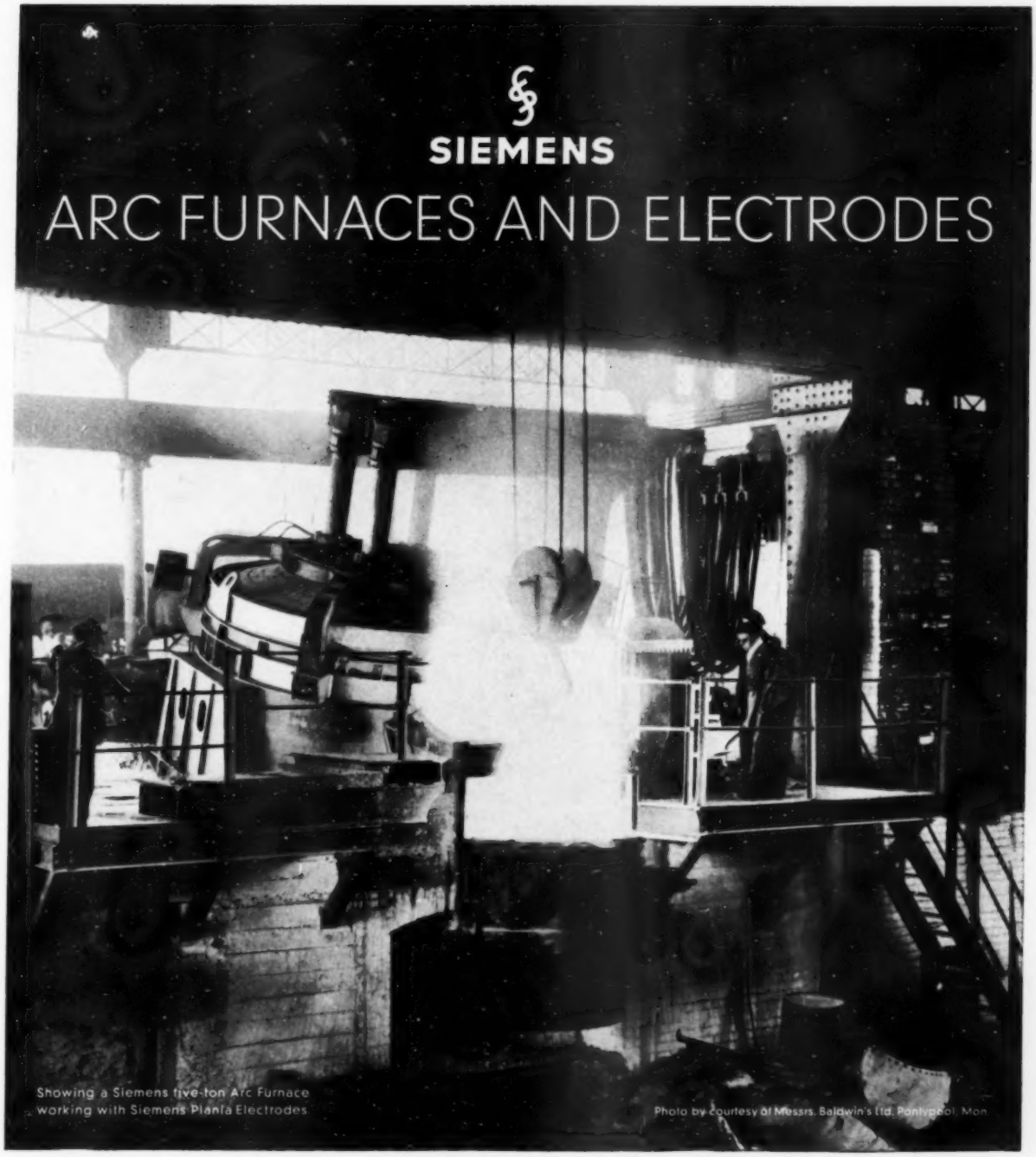
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Electric Drives in the Steel Industry

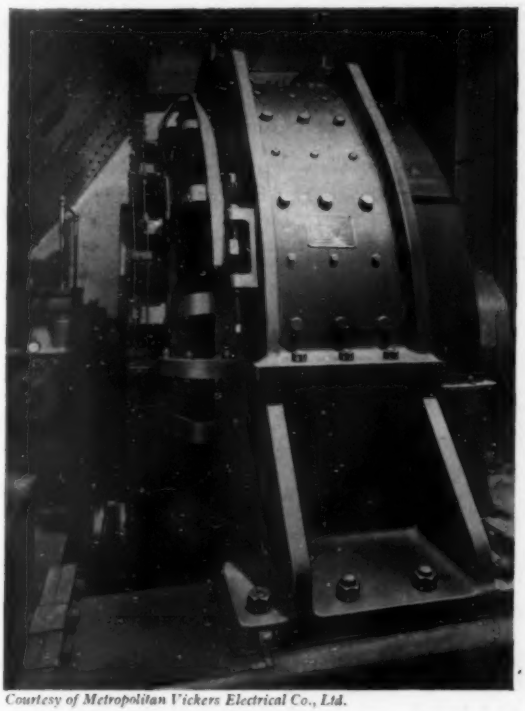
The past year has witnessed great progress in the steel industry which has resulted in many new installations. In this article brief reference is made to some of the electrical equipments involved, and to important contracts on hand.

DEVELOPMENTS in metallurgical processes during recent years have shown the need for accuracy and control of power, and in this direction electricity has shown itself to be of inestimable value. Especially in the steel industry is electricity of great value in the distribution of power and in its utilisation in mechanism. Although this industry is dependent on coal, recent progress has shown that it works through mechanism actuated largely by electricity. The electrification of steel works has been proceeding for many years, but considerable progress has been made during the past year, not only in the further application of this power medium, but in electrical engineering developments of great importance to the industry. There has, for instance, been increased business in control gear and the steel industry has made big demands for special types of control gear.

A range of sheet-steel cubicles for contactor starting equipments for various rolling-mill auxiliaries has been standardised by Metropolitan Vickers, Ltd. These equipments comprise a sheet-steel cubicle to accommodate contactors, control relays, and an interlocked isolating switch with provision for adding busbars. The busbars and isolating switch are in a separate chamber arranged at the top of the cubicle, and the layout adopted provides for cubicles to be mounted together, and through busbars, fitted to form a multi-panel board with single incoming cable-box and outgoing cable-boxes to the respective motors. A feature of these equipments is the rapidly-increasing use of magnetic time relays to control the acceleration of the motor, in place of the former types of relay which were of the current-controlled or mechanically-time-controlled pattern. The magnetic time-control relay has a time characteristic dependent on the rate of decay of the magnetic field, and it is, therefore, independent of the variations in ambient temperature or line-voltage conditions. The relay is of very robust construction having knife-edge bearings, instead of pivot pins and silver-faced contacts. It will operate over very long periods with the minimum of maintenance, and is ideally suited for steel-works duty.

Another development for the steel industry is in connection with the individual drive of live rollers, the control gear in this case consisting of a main contactor reverser for the complete group of motors, and individual protective units having self-resetting overload devices for the separate motors. These protective units are arranged for plugging into a busbar distribution system, thus forming a ready and convenient means of isolating any motor and starter by merely withdrawing the starter from its plugged-in position on the busbars.

A revised scheme of control has been developed for the Ward-Leonard control of rolling mills which involves controlling the exciter field by means of special motor-operated regulators, and thus dispenses with the use of separate contactors and relays in the field circuit, thereby reducing very considerably the number of control auxiliaries. These motor-operated regulators are provided with an ingenious form of follow-up device arranged so that whilst the position of the regulator arm is under the control of the operator its speed of operation is controlled by the pre-determined setting of the regulating device. The use of the motor-operated regulator and the follow-up device reduces the effort required for operating the equipment, and materially lightens the labour of so doing.



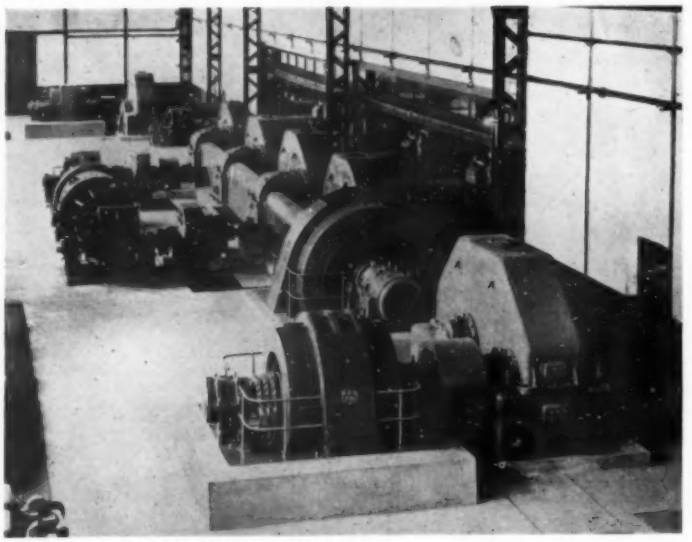
Courtesy of Metropolitan Vickers Electrical Co., Ltd.

Roughing-mill motor 2,900 h.p., 650 volts d.c., 0/60/150 r.p.m., at the Briton Ferry Steel Co.'s new sheet-bar mill.

Some Rolling-Mill Installations

The construction of equipment for large reversing mill drives has been well maintained by Metropolitan Vickers Ltd. All these drives now incorporate the sytem of automatic control of the driver's operation. This system ensures that after the driver has moved his controller, rates of acceleration and deceleration and limitation of peaks are automatically controlled by a system of special exciters. These are simple in construction, and eliminate a number of small control devices, so that reliability is much increased. One such equipment is being supplied to the South Durham Steel and Iron Co. Ltd., for a two-stand Plate Mill, comprising one 1,865/5,750-h.p. and one 1,865/6,550-h.p. reversing motor supplied from a flywheel Ilgner set consisting of four 755 kw. d.c. generators, and one 2,700-h.p. slipring induction motor. An automatic slip regulator and ventilating equipment, also high- and low-voltage switchgear are included in the contract.

An important contract completed during the year by the British Thomson-Houston Co., Ltd., was the conversion from steam to electric drive of a large reversing rolling mill producing rails and sections at the works of the Shelton Iron, Steel and Coal Co., Ltd. The motor of this equipment is rated 3,800 h.p., 62/160 r.p.m., and is designed for a maximum peak load of 11,400 h.p. It is supplied from a flywheel motor generator set. Another interesting installation by this company is a 4,500-h.p. synchronous induction motor for driving a continuous billet rolling-mill at Messrs. Stewarts and Lloyds, Ltd., Corby, the consulting engineers on this contract being Messrs. H. A. Brassert and Co., Ltd. As part of the same drive are installed two 2,000-h.p. induction motors for tandem billet mills, three 500-h.p d.c. motors with common motor generator set driving edging stands, and all necessary auxiliary motors and control gear for the above-mentioned continuous and tandem mills, and for a 40-in. blooming mill and a 32-in. reversing mill. Metropolitan Vickers Ltd. are supplying considerable electrical equipment for these steelworks, which include the equipment for four mills—one three-high billet mill driven by a 4,000-h.p. 500 r.p.m. induction motor; two three-high merchant mills driven by 1,000-h.p. 600-r.p.m. and 800-h.p. 750-r.p.m. induction motors, respectively; and a sheet mill, the drive for this being an induction motor of 800 h.p. at 750 r.p.m. Special reference should also be made to a cogging mill motor by the General Electric Co. Ltd., for a peak load of 20,000 h.p. for the Cleveland Works of Dorman Long and Co., Ltd., including other electrical rolling-mill equipments which have been built for this works.



By Courtesy of the British Thomson-Houston Co., Ltd.

The electrical installations in the motor-house of the billet rolling-mill at the Corby Works of Messrs. Stewarts & Lloyds, Ltd.

Important Contracts in Hand

Amongst rolling-mill drives in course of manufacture is one for a new merchant bar and strip mill. The equipment consists of one 700-h.p., one 500-h.p., and three 350-h.p. d.c. motors for the roughing mill; two 500-h.p. and two 350-h.p. motors (with a synchronous speed tie between them) for the intermediate mill; and one 2,000-h.p. motor for driving the stands of the finishing mill. All these motors are supplied from a 3,750 kw. synchronous motor-driven motor-generator set. The B.T.H. Company is also manufacturing the necessary control gear and switchgear for this equipment.

For the main drive of a new tandem wide-strip cold rolling mill there is being manufactured a 750-h.p., 300/600-r.p.m., and three 1,500-h.p., 300/600-r.p.m. d.c. motors. These motors, and a 225-h.p. reel motor, will be supplied by a synchronous motor-driven motor-generator set. There is also being manufactured a 750-h.p., 300/600 r.p.m. d.c. motor for a single-stand cold-rolling mill, and a 225-h.p. d.c. reel motor for this mill, both these machines being supplied from a 500-kw. generator included in the motor-generator set previously mentioned. Chief interest, however, centres in the control gear for these two mills which is very elaborate in order to give fullest possible control.

Considerable interest is attached to the hot- and cold-strip and tinplate mill for Richard Thomas and Co., Ltd., at Ebbw Vale. The electrical plant being built by General Electric Co., Ltd., includes three d.c. motors, each of 1,500 h.p. output which together with a 400-h.p. d.c. motor are being supplied from a 3,500-kw. synchronous Ward-Leonard set. Further equipment includes two 11,000-volt remote-controlled metalclad switchboards, one of 18 panels; transformers; and 150 d.c. reversible steelworks motors. The majority of the mechanical plant required for the cold-rolling section of the scheme is being constructed at the Fraser and Chalmers Engineering Works of this company. Mention may also be made of the electrical equipment for the new tube works at Jarrow, comprising motors ranging in size up to 720 h.p., control gear, switchgear, transformers, etc.

A reversing mill equipment has been ordered from Metropolitan Vickers Ltd., by United Steel Companies Ltd., for a new four-high 7-ft. plate mill, at the works of the Appleby-Frodingham Steel Co., Scunthorpe. The main motor is rated at 3,500/11,550 h.p. at 50/90 r.p.m., and is supplied by a flywheel Ilgner set having four generators. The induction motor of this set is 3,000/6,000 h.p., and each generator is of 1,500/5,400 kw. rating. Two of the generators supply the reversing mill motor, and a third is used to increase the capacity of an existing mill motor, whilst the fourth is a spare which can take the place of any of these three or of generators on another set. The equipment also includes three exciter sets, one of which is a spare, and the modernising of the present control scheme on the existing 7-ft. plate mill.

Other electrical equipments by the same company include those for working two edging rolls on a finishing bar mill for the Briton Ferry Steel Co. Ltd. This equipment is the first of its kind to be manufactured in this country. Each roll is driven by a 250/655-h.p. vertical d.c. motor. The two motors are connected in series and fed from the existing generator which supplies the motor driving the main rolls. The scheme of control is so arranged that when the driver operates the master switch, in addition to controlling the main roll motor, he also controls the edger motors, which automatically synchronise with the main drive, and follow the variations in speed of the main rolls.

Large push-bench-drive equipments are also in course of manufacture for Messrs. Stewarts and Lloyds Ltd., for their works both in Australia and South Africa. For the former, a 0/1,050-h.p. motor, 0/40/80 r.p.m. direct-coupled to the push-bench rack pinion is being supplied. The peak rating of the motor is 2,750 h.p. The motor-generator set consists of an 880/2,850-kw. generator driven by a 1,100-kva. synchronous motor which maintains its leading power factor constant at all loads. A feature of the main bench control gear is a completely new design of over-run prevention limit switchgear which ensures accurate and positive stopping of the bench. The push-bench for the South African works is driven by a 0/1,300-h.p., 0/250/500-r.p.m. motor with a cut-out peak of 3,200 h.p., coupled to the rack pinion through a two-speed gearbox. The motor generator set consists of a 1,550-h.p. induction motor driving a 1,050/2,600-kw. generator.

Sheet-catcher Gear

In conjunction with Messrs. Wellman Smith Owen Engineering Corporation Ltd., and the Incandescent Heat Co., Ltd., Metropolitan Vickers Ltd., has taken a leading part in an interesting development in the mechanisation of sheet mills by the provision of automatic sheet-handling equipment. Four equipments have just been completed to the order of the above-named companies for installation at various works in this country. The electrical equipment for each of these installations comprises two chain-driving motors and two table-lifting motors with contactor-control equipment and driver's control pillar. The motors for these drives are of special construction designed to operate at the rate of 40 reversals per minute without exceeding 75° C. rise of temperature under normal conditions of service. The contactor-control equipment has also been specially designed to cater for this very severe duty. In addition, equipments have been supplied for the drives and control of equipment used in conjunction with the above mills, including furnace chains, conveyers.

The Relation Between the Mechanical Properties of Ferrous Materials and the Liability to Breakdown in Service

By L. W. Schuster, M.A., M.I.Mech.E., M.I.E.E.

The results of none of the most commonly adopted mechanical tests can be co-related with the usual failure in service, said Mr. Schuster, in discussing the above subject at a recent meeting of The Midland Metallurgical Societies. In this article are presented some of the main features of the discussion.

METHODS of testing such as are called for in purchasing specifications may be excellent in so far as they act as a check on the quality of the material, but standard tests, so far as they are intended to give information that is useful in judging the suitability of materials for service, are certainly very deficient. It is not so long since the author advocated a certain test for some important welded joints, when the purchaser replied that he could not understand the function of that test, whereas he did desire a tensile test, which was one he could understand. He added that it served the purpose of showing the load the material would withstand before it could be pulled asunder. Unfortunately, however, a part in service was not pulled out until it fractured, as in a tensile test. Though a consequential failure may take place in this manner, a fracture in service resulted from a creeping crack, or a sudden rip from an initial crack, in either case without measurable distortion. The value of the tensile strength of the material therefore, has no direct bearing on the usual failure, and though, within limits, it may be true that the fatigue value of a material is proportionate to the tensile strength, such an occurrence can only be looked upon as fortuitous, and any such happening was not taken into consideration when the remark was uttered.

Yield Point

The use of the yield point is often recommended as a basis of design, but fracturing in service has never been due to an unsatisfactory yield point. Naturally, the measurement of the yield point affords an excellent check in ensuring that a manufacturer is obtaining the class of steel ordered; it is also of importance in the design of columns and certain parts liable to fail by collapse. Troubles arising from such considerations do not, however, constitute fracturing in service. The aim in designing a part should clearly be to ensure that the properties of the material are suitable for resisting the form of failure feared most, and, for the general design of machine parts, the use of the yield point as a basis is definitely wrong. Should the part work under severe conditions of shock, to raise the yield point is just the opposite of what is required. An important objection to the yield point is that, for an alloy steel, its value may be raised as much as 115%, while the fatigue range is raised by only 40%. A low yield point in certain parts is by no means a disadvantage, but may actually prove to be an advantage, in so far as it readily enables a material to adjust itself to the piling up of the lines of stress at a discontinuity. As a general basis of design the use of the yield point is unsatisfactory, if only because the measurement does not represent a fundamental property of a material, and many materials have no yield point. A heat-treated alloy steel does not usually give a definite yield point, such as is given by a mild steel, and the characteristic of a mild steel, which allows an appreciable strain at the yield point without increase of stress, has certainly a distinct advantage. Further, it may be cited that, in commercial testing, the accuracy of the value of the yield point recorded on the test-sheet is often open to considerable suspicion.

Limit of Proportionality

On the question of the limit of proportionality nothing need be added to the remarks on the yield point. When breakdown in service is under consideration the measurement of the limit of proportionality is even less value than the yield point. It bears no relation to the mechanism of failure under fatigue, and any insignificant work-hardening of the material would cause its value to be altered at will. Such a basis certainly would not necessarily give benefit to a heat-treated alloy steel, as the load-extension diagram for such a material may start to tail off with zero load.

Ductility

Ductility obtained by various methods is generally considered to be the most important property, yet all methods miss the mark in giving information on the real characteristics of materials that determine their behaviour in service. In a consideration of results, the average interpretation of the elongation, measured on a tensile test, is perhaps the most erroneous. Comparison of the figures do not afford any guide as to the relative manner in which two different grades of material will behave in service. When the word "ductility" is referred to, the intention is in reality to refer to that property which it represented by the measurement of the reduction in area in a tensile test. The same property is obtained approximately by measuring the elongation on an infinitely small guage length, and the same proerty is indicated approximately when a bend specimen first fails. It can be safely said that there is no connection between this ductility

and the liability to mechanical breakdown, though it is perfectly true that good ductility has shown itself to be an invaluable asset, yet that is no proof whatever that, if one material gives a reduction in area of 60%, and another only 40%, the one giving the higher value will give better service. In fact, the reverse might readily take place. A crack spread in a service part with no appreciable plastic deformation of the material, and the measured ductility is certainly not developed. Naturally, as for other test results, the measurement of the reduction in area ensures that a given material is up to standard quality.

Bend Tests

On the question of the bend test, it can be said that when this is carried out in a methodical manner, the first crack would break out after a certain degree of deformation, which is approximately calculable from measurement of the reduction in area in a tensile test. The test, if made to determine ductility, is clearly redundant if the ductility of a material has already been obtained by other means. It, however, affords a cheap and rapid method of determining ductility, which can be used in lieu of other methods, or, on occasions, when the reduction in area is not or can not be measured in a tensile test. For material that is to be subjected to cold deformation, during the later stages of manufacture, it is certainly useful.

Fatigue Testing

Undoubtedly, the method of applying the load in a fatigue test approaches the conditions of service more nearly than that in any other test, even though it is not a regular works test. If, however, it is assumed that the fatigue range bears an approximate ratio to the ultimate strength of the material, the test fails to give information not given by knowledge of the value of the latter quality, and to make the test serves no useful purpose. Moreover, the fatigue strength, as commonly determined is by no means a true criterion of the liability to fail in service, and other properties of material must therefore not be disregarded.

Properties for Severe Service Conditions

One of the most useful properties of material for resisting severe service conditions is its capacity for yielding without appreciable increase in the load, and a material giving a well-marked yield point at which there is appreciable strain, such as mild steel, is probably the most suitable for withstanding rigorous service. This points to the particular importance of the fatigue or bend test, when made on a notched specimen, either test being carried out up to the point of first failure, and then discontinued. Such tests are able to give information on the capacity of material to accommodate itself to stress concentration at a discontinuity.

Notched Bar Tests

As regards the Izod test, the result of this test does not essentially show the capacity of materials for withstanding impact. The velocity of any such notched-bar test, as usually applied, is far too low for such a purpose. Though the result depends upon several factors, on which it is not proposed to enlarge, it may be said that the final stage of the test does afford an indication of the ease with which a crack will spread through metal, after it has once been formed. This phase of the test is related to service failures, inasmuch as, when an incipient crack broke out in a machine part, there is certainly an advantage for the material to have a high resistance to the spread of the crack. It seems that, in considering the usual failure of service, the earlier part of the notched-bar test is decidedly of the greater importance, in so much as the energy expended during the early stages of fracture shows the relative capacity of different materials to deform at a notch without initial cracking, and therefore, in a measure, shows their capacity for standing up to stress concentration at a notch. The test, when results are duly considered, certainly shows fthe capacity of a material to deform without extension of the initial crack into the body of the specimen. It must be agreed, however, that the Izod test, which gives an integrated value during all stages of the test is a clumsy method of obtaining this information. The opinion has frequently been expressed by some of the most eminent and experienced authorities that a study of service failures shows that failures are far more common in materials that gave a low Izod value, and that a good Izod value is undoubtedly conducive to satisfactory behaviour. Such evidence cannot be ignored, but, if accepted, it seems that the significance can not lie in the capacity of the test for detecting the resistance of material to the spread of a crack, which incidentally, is often considered to be the prime value of the test. The brittle failure of a material may not take place until after an appreciable amount of energy has been expended, and, moreover, it does not commence before an initial crack has been formed. Seeing that when a material has developed even a minute crack, it has already mechanically failed, a high Izod value due to toughness cannot reduce the number of failures. The significance of the evidence must therefore lie in the capacity of the test to discriminate between materials that offer good and indifferent resistance to the inception of a crack, that is, under conditions of concentrated stress.

Forthcoming Meetings

INSTITUTE OF METALS.

LONDON SECTION.

Feb. 10. "Age-hardening," by Marie L. V. Gayler, D.Sc.

NORTH-EAST COAST SECTION.

Jan. 29. "Randrupson Process of Cement Moulding," by F. W. Rowe, B.Sc. Joint meeting with the Newcastle Branch of the Institute of British Foundrymen.

SCOTTISH SECTION.

Feb. 14. "Some Notes on Aluminium Alloys in Road Transport," by G. Mortimer. Joint meeting with the Scottish Centre of the Institution of Automobile Engineers.

SHEFFIELD SECTION.

Feb. 11. "Large Non-ferrous Castings," by J. E. Newson, M.Met.

SWANSEA SECTION.

Feb. 8. "Industrial Furnaces," by S. J. Fallon.

MANCHESTER METALLURGICAL SOCIETY.

Feb. 2. "Electro-deposition in the Engineering Industry," by J. W. Cuthbertson, M.Sc.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Jan. 25. "Architectural Engineering," by R. T. James.

INSTITUTION OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Feb. 4. "Toughness of Cast Irons from Transverse Stress-strain Curves," by G. L. Harbach.

EAST MIDLANDS BRANCH.

Feb. 12. "Melting of Cast Iron," by S. E. Dawson, F.I.C., at Nottingham.

Feb. 14. "Alloy Cast Iron," by P. A. Russell, B.Sc., at Lincoln.

LANCASHIRE BRANCH.

BURNLEY SECTION.

Feb. 8. "Some Aspects of Loam Moulding," by A. J. Hinton.

LONDON BRANCH.

Feb. 2. "The Casting of Commercial Ingots," by W. A. C. Newman, B.Sc.

EAST ANGLICAN SECTION.

Feb. 7. "The Melting of Cast Iron in the Rotary Furnace," by S. E. Dawson, F.I.C.

SCOTTISH BRANCH.

Feb. 12. "Some Impressions of Modern Iron Foundry Practice in the U.S.A.," by A. B. Everest, Ph.D., B.Sc.

SHEFFIELD BRANCH.

Feb. 3. "Machine-cast Pig Iron," by J. C. Jones.

WALES AND MONMOUTH BRANCH.

Feb. 5. "Patterns and their Relation to Moulding Problems," by S. A. Horton. At Cardiff.

WEST RIDING OF YORKSHIRE BRANCH.

Feb. 12. "Steam Pressure Feeding," by Ben Hird.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Britain's Prosperity

GREAT BRITAIN has experienced a recovery in trade during the past year, and her industries have been producing at an increasingly rapid rate to meet pressing demands. This wave of growth which commenced slowly about 1932, has gradually accelerated, and some assert that the peak has been reached and that there are indications of slackening demand. To what extent rising prices of raw marerials are influencing the demand it would be difficult to say, but it is a factor which tends to slow down the growth of both trade and industry. Of re-assuring significance, however, is the great activity of the iron and steel industry where plant and personnel continue to be engaged at full capacity, and are likely to be far into this year.

Various industries have been greatly assisted by armament orders, by contracts relating to new factories, new factory equipment and works' extensions, the programme of public works, railway improvements, and other work of a like character, and those in progress and contemplated will continue to provide employment for men and machines for some time to come, but it should not be overlooked that by far the greater amount of work performed and in progress is concerned primarily with supplies for markets at home and abroad. The greater demand for raw materials has greatly increased imports, and it is gratifying that substantial increases in the export trade have been experienced. Recent figures show that total exports amounted to £596,761,000, an increase of £95,387,000 on 1936. It should be noted also that imports show a substantial increase of £181,313,000 to £1,029,065,000. This overseas trade, however, is a sufficient indication that Great Britain is at present enjoying a phase of prosperity and, while fluctuation cannot be avoided, the prospects for a continuance of this phase are reasonably bright.

Much credit for the present position of this country is due to the National Government. Its policy of providing cheap money, the Ottawa Agreement, various trade agreements with foreign countries, building programmes, and the armament programme, have all contributed towards recovery, and the present state of prosperity. The Ottawa Agreement in particular has been distinctly helpful; increasing trade between nations of the British Commonwealth has in fact been one of the most important features. In addition, the various efforts made to improve foreign trade have been successful in comparison with the years immediately preceding last year, but it should be remembered that the trade balance with almost every country from which Britain imports is against her, there is therefore ample scope for more intense efforts to approach more nearly to a trade balance.

The recent announcement that the informal discussions between the British and United States Governments, which has long been in progress, had reached a point which made it possible to enter upon direct negotiations for a trade agreement between the two countries, is another effort that may prove successful in further increasing trade. Formal notice has now been issued by Mr. Gordon Hull of the intention of the United States to negotiate a trade agreement with the Government of the United Kingdom and with the Government also on behalf of Newfoundland and the British Colonies.

It is noteworthy that Mr. Hull revealed that tariff concessions to Britain would be considered on 416 categories of goods. Of these attention is especially attracted by references to agricultural machinery, motor-cars, iron and steel products, textile machinery, steam turbines, cutlery, and—significantly—guns. Many of the goods concerned are already on the free list, no doubt with a view to strengthening the case for reciprocal bargaining. Many interested American manufacturers will protest against the inclusion of various categories in the list, and their views must be submitted to the Committee for Reciprocity of Information by February 19. In business circles in America, however, it is recognised that bargaining should be opened with a comprehensive list, and Mr. Hull will be able to justify his initial gesture.

The proposed negotiations with a view to closer economic co-operation between the two countries are full of difficulties and a possible source of danger to British industry. It must be remembered that the advantages of American entry into the British Commonwealth's trading family has been pointed out by business men who show how much trade America has been losing since the Ottawa Agreements were signed. For many years the trend in America has been towards self-sufficiency, and this is still a disturbing influence in international trade. The United States possesses the largest self-contained market for food and manufactured goods in the world. Behind the shelter of a prohibitive tariff barrier she has been able to organise vast plants equipped with machinery and appliances for mass production to a degree not open to other countries which do not possess a domestic market of similar dimensions.

A recession in trade, the magnitude and duration of which cannot be forecast, is, unfortunately in progress in the United States. There is thus every inducement for her to seek openings both in Europe and British markets oversea for the surplus of goods which her internal market, under present conditions, cannot absorb. In considering reciprocal trade it should be remembered that the American tariff, which has been raised at least twice since the war, is one of the highest in the world. So prohibitive has its level become that the United States takes not more than one-third of what we buy from her. There is certainly room for a considerable levelling up in reciprocal trade by a reduction of the American tariffs, but any special facilities given with a view to increased imports of American products should be very carefully investigated. Any tariff concessions conferred upon America would be enjoyed automatically by other industrial countries with which trade agreements include the most-favoured-nation clause. Such countries as Germany and Japan, with which competition is already a disturbing feature, would benefit.

The desire for freer international trade to maintain the condition of prosperity is very real, but only on a reasonable reciprocal basis, we hope and believe that it is no longer possible to use the United Kingdom as a dump for surplus products. Any agreement therefore, which may be arranged, should provide such a measure of flexibility which will permit its modification or even termination at very short notice, should changing economic conditions render it necessary for the protection of British interests. With reasonable and proper safeguards, closer economic co-operation between the two countries should be beneficial and assist in the maintenance of prosperity in this country.

Non-Ferrous Metals Outlook

THE progress during the past year in the majority of the engineering, shipbuilding and manufacturing industries has had a considerable influence on production and price of the non-ferrous metals in particular. Although supply and demand continue to be important factors in determining the price of commodities, the maintenance of stable prices for the basic materials consumed is an important factor in the continued success of the principal manufacturing industries. Metal consumption fluctuates in the course of a year, but many interesting points regarding non-ferrous metal production and demand were given in a recent address by Mr. P. E. Marmion.

The abnormal conditions which prevailed in the first quarter of 1937, with activity in shipbuilding, building construction, motor car and commercial vehicle manufacture general and electrical engineering, and a number of other trades, coupled with world-wide rearmament, sent consumption to a total that created a corresponding rise in prices. The progress of recovery was, however, retarded by the reflection of these rising prices on the cost of manufactured goods and, as would be expected after a period of such sharp activity, a reaction commenced, starting rapidly in March and continuing a downward movement to the present time. There has been no serious deterioration in the stock position of lead and very little in the case of spelter, while steps have been taken to keep production and consumption of copper in a state of equilibrium. Recovery in America has continued to lag far behind the rest of the world, although the basic reasons are more political than economic and conditions can be expected to react to a change in policy.

The heavy demand for lead throughout 1936, resulted in heavy incursions on stocks; United States consumption exceeded production by 80,000 tons and was 90,000 tons beyond the total for the preceding year, but even so American consumption was only 67% of the 1929 peak. In other countries the consumption total expanded by 73,000 tons to reach the record figure of 112% of the 1929 peak. Demand exceeded production to the extent of 20,000 tons and it was unfortunate that these had to be met from already depleted stocks, creating that market anxiety which was a feature of the early part of 1937. Of these other countries, Great Britain, Belgium, Japan and Russia attained new levels and Germany very nearly reached her 1929 record.

The total world production of lead was 1,469,780 tons in 1936 and consumption was estimated at 1,571,000 tons, or an increase of 167,000 tons over the consumption for 1935. The total world production of lead for 1937 is estimated at 1,680,000 tons which would represent 110,000 more than actual consumption for the year.

Spelter also attained a record for production and consumption in 1936, production being 1,473,412 tons and consumption 1,505,000 tons, increase of 150,000 and 175,000 tons respectively over the figures for the preceding year. The production of spelter in 1936 was 4,000 tons greater than that of lead, the economic production of the higher grades of the metal having increased its importance.

Production is estimated at 16,300,000 tons for 1937, an increase of 160,000 tons as compared with 1936. In spite of this substantial advance in production, consumption has been maintained at comparative levels until September. Production of spelter in the U.S.A. was 82·8% of the 1929 figure, but consumption increased to 96·2% of the 1929 datum, whilst the rest of the world had percentages of 113·6 and 109·1 for the production and consumption comparisons.

Although spelter has attained a position of increased importance in the field of industry, the production of both the metal and zinc concentrates remains the least satisfactory of all non-ferrous metals to the producer, and it is only in periods of exceptional metal prices that producers have the opportunity of covering themselves on such items as mining transport or milling of zinc concentrates and on the capital cost of the power and treatment plants that production entails.

The 1936 production and consumption of copper both showed substantial increases over 1935, the 1936 production figure of 1,639,714 tons representing an increase of more than 200,000 tons and the 1,850,000 tons consumption representing an advance of 250,000 tons. The expanded consumption logically enough caused a recession in stocks and this was rectified by a progessive increase in the quotas by which producers were restricting their output, this relaxation in quota restriction commencing in August with an advance from 70 to 75% in agreed production, and this reached 105% in November when consumption-production equilibrium was attained. World stocks of copper were approximately 725,000 tons in 1933, and these were reduced to 400,000 tons by the end of 1936, and to only 340,000 tons by October of 1937, representing less than three months supply.

Metal prices fluctuated under two distinct and opposite trends in the year, moving upward from July to March and reversing the trend with severity from April to June. From July to March, the price of lead rose from £15 to £36, spelter from £14 to £37, and electrolytic copper from £41 to £81. The recession which followed in the next period brought the price of lead from its peak of £36 in March to an average of £22 16s. 4d. for June, spelter from a peak of £37 to an average of £21 9s. 4d. and copper from £81 to an average, in June, of £62 5s. 10d. At the end of the year each metal stood at about 50% above the price at the opening month.

Great ore reserves have been brought to light and a considerable excess tonnage is expected; development work is nearing completion in the favourable zones and the prospects are good for the increased consumption of basic non-ferrous metals.

Correspondence

Soldering of High-Duty Brasses

To the Editor, METALLURGIA.

Sir,—In Mr. Hudson's article in your October issue, he states: "The high-duty brasses are easily machined, and they can be readily soft-soldered . . ."

I think it should be remembered that there is a distinct risk of failure by intergranular penetration. The phenomenon was first described by Dickenson (J.I.M. 1920, No. 2, page 315), and has been commented on by subsequent writers.

The penetration is worse in the case of pure beta brasses, but the alpha plus beta are not free from it. I have seen several failures through the soldering of H.T. brass castings and, therefore, think that a note of caution is desirable.

Dec. 16, 1937, Yours, etc.
Glasgow. J. ARNOTT, F.I.C.

Sir,—I note Mr. Arnott's remarks in connection with the above, and concur with his statement in regard to the risk of failure by intergranular penetration. As pointed out by Mr. Anott, the penetration of high-duty brasses by solder is worst on those alloys having a full beta structure and the alpha/beta alloys are also affected to some degree. For high-duty applications accordingly it is a wise precaution to ensure the absence of soldering on any stressed structures.

In remarking upon this matter in the article in question, it was intended to differentiate between the fact that alloys in this class can be readily soft-soldered, whilst other bronzes, such as aluminium bronze, cannot be soldered in the normal way.

London. Yours, etc.,
F. HUDSON.

The Hot and Cold Working of Malleable Cast Iron

By JOHN V. MURRAY

Investigations are described on the hot- and cold-rolling of malleable cast iron and the results show that, with reasonable care in the preparation and treatment of suitable material, these operations can be successfully performed and the rolled material possess increased mechanical properties.

IN order to simplify a design and also to economise in the production of many small parts, it was considered that malleable iron castings could be wrought to an extent which would improve the tensile properties of the material and also effect some saving in production. To test the possibilities of the idea a few simple experiments were carried out, one of the first being in connection with a tool holder. This holder previously required the drilling of two holes in a malleable casting two holes in a cutting blade and two rivets to secure them together. The rivets were subsequently cast on as part of the holder and the blade rivetted in position. At first these cast-on rivets were heated for hammering-up but it has been found that they can be hammered cold without detriment.

This method reduced labour charges and wear and tear of drills; the finished article looked neater than by the previous method of manufacture and although the tools held in this way have been in frequent use over a long period no breakage has yet been reported. This, together with other experiments, convinced the writer that malleable cast iron has many properties which are not fully appreciated and led to an investigation on the hot- and cold-working of this material which is described in the following notes.

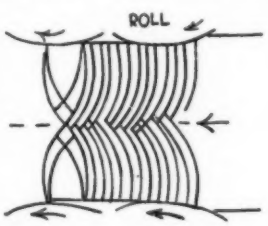


Fig. 1.—Direction of deformation.

According to the authors of some text-books, deformation during rolling takes place through the outside of the rolled bar being drawn forward relative to the inside, but Korber showed that the opposite is the case. Actually, the centre portion is pushed forward, relative to the outside of the bar, due to deformation taking place along certain flow lines in the material, Fig. 1.

To test this latter theory a bar of mild steel was drilled with a series of holes in a straight line along the centre of the bar, and the holes plugged with round brass rod. The bar was then cold-rolled with the plugs at right angles to the roll face and the bar fed into the mill in the same direction for each pass. Afterwards the bar was sectioned to show the deformation of the plugs in relation to it. The shape of the brass plugs, Fig. 2, indicate that deformation takes place approximately similar to the flow lines in Fig. 1. With a proper appreciation of the action of deformation some of the peculiar failures encountered in subsequent rolling experiments will be understood.

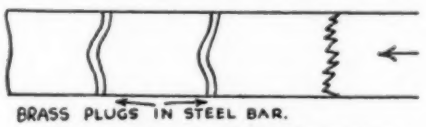


Fig. 2.—Test showing deformation direction.

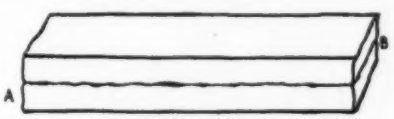


Fig 3.—Fractured specimen bar.

Hot- and Cold-rolled Malleable

Samples of whiteheart malleable cast iron were prepared by moulding small bars, 8 in. × 1 in. × ¾ in. in size, these were annealed for six days in a packing of 1–5 red oxide of iron at a temperature of 1,000° C. at the top of the furnace which was pyrometrically controlled. After cooling they were cleaned by sand-blasting.

The first experiment.—A bar was heated and, owing to the need for slight adjustment to the rolling mill, it was held in the furnace too long, and at too high a temperature. At the first pass the bar parted into two longitudinally. The work applied having caused it to break along the line AB in Fig. 3. The bar gave the impression of having been cut with a rough knife. Before proceeding it was decided to examine this bar. The microscope revealed that breakage had occurred where the carbon was super-saturated and free cementite had reformed from the deposited carbon. Free cementite, when massive cannot be rolled in any ferrous material; it is very brittle at high temperatures. The microphotograph Fig. 4, shows that carbon has gone back into solution, and a eutectic had formed. Veins of free cementite enmeshed saturated grains of pearlite, islands and zones of free cementite persisted. There was no grain growth in the ferritic areas. The cored structure has disappeared. Innumerable nodules of carbon were

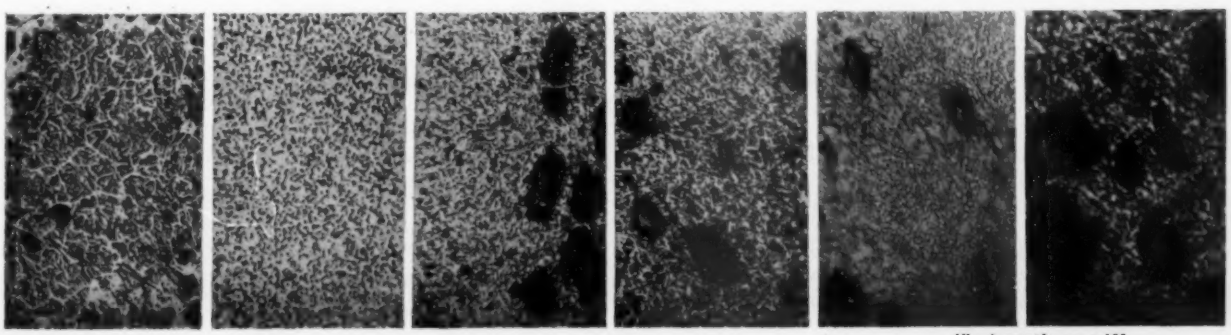
Fig. 4.—Structure of specimen rolled at too high a temperature.

Fig. 7.—Fine outer zone of the second specimen.

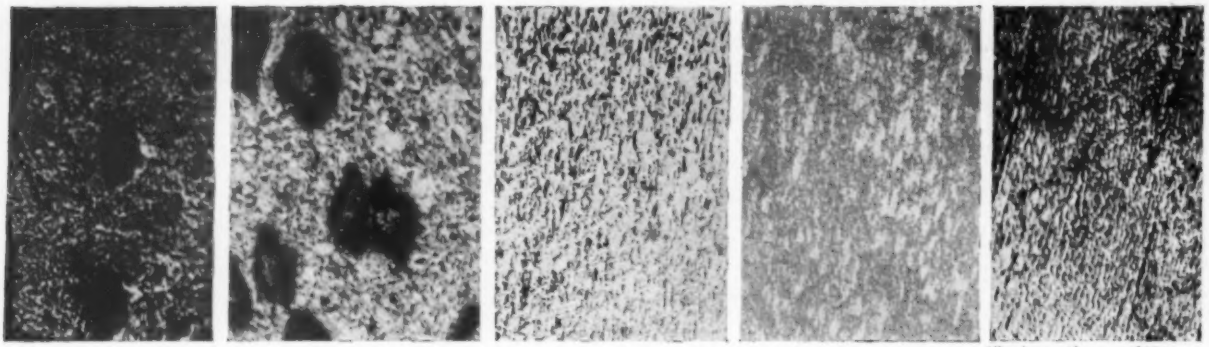
Fig. 8.—Showing elongated graphite in second specimen.

Fig. 9.—Structure of worked specimen after normalising.

Fig. 10 and 11.—Outer and inner zones of the third specimen. Note the increase of nodular carbon at centre.



All micrographs are ×100.



All micrographs are ×100.

Fig. 12 and 13.—Outer and inner zones of worked specimen subsequently normalised.

Figs. 14, 15, and 16 show surface zones from outside, inside and centre of bar: note carbon slits in Fig. 16.

gathered up just on the outside of these cementite zones. This indicates that high temperature annealing of malleable cast iron actually retards the annealing process, because it assists the retention of cementite which must not be present if the material is to possess its malleability.

Further experiments were conducted at a much lower temperature, i.e., at about 950° C., and the work applied very gently at first. With four passes between the rolls, and the reduction only 50% of the original, an excellent finish was produced. Some of these bars were reheated and given another four passes and the reduction increased about 80%. Again a fine finish was apparent.

Effect of Heavy Work.—To obtain a reduction of 75% with six passes resulted in the ferritic and slightly oxidised edges cracking, as in Fig. 5. This spoils the finish and causes many incipient cracks to start and travel along the grain boundaries which renders the metal useless.

With eight passes, as in the second series of experiments, and a further two, i.e., four original passes, the bar reheated and given a further six passes, a total reduction of 95%, the limit of work which could be applied was approached. By this time the bar was well below the A arrests and much distortion had taken place. The bars had tried to assume the shape of the rolls. Attempts were made to straighten the rolled material, but each time fracture occurred. The bars were reversed and rolled to find out the effects of cold work, and, although they did elongate, each fractured along the centre, the parts being splayed as in Fig. 6. It was found that this fracture had occurred at the point where the metal was saturated with pearlite. These bars were intensely hard before this further rolling and this treatment made them harder still, but as the bars had fractured by this treatment they were not pursued further. The specimens were examined under the microscope and tests were made which are recorded in the following :—

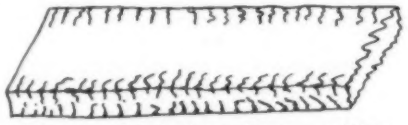


Fig. 5. — Cracked specimen resulting from heavy initial work.

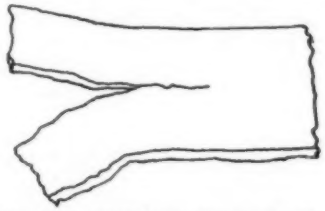


Fig. 6.–Fractured specimen resulting from heavy final work.

Bar No. 2.—This bar had had four passes only and was cooled on the floor from just above the critical range. A feature of the micrographs, Figs. 7 and 8, is the elongation of the globular nodular carbon. Very fine veins of cementite are around each saturated grain whilst there is a fine structure of ferrite and pearlite on the outside area. This bar, which gave a tensile strength of 36·1 tons per sq. in and a Brinell hardness of 187, could have been reduced much more. There was no massive free cementite present in the centre.

A bar of this type was treated the same way and afterwards normalised. The structure became much coarser, especially in the ferritic zones, and the oxide peel reappeared but was thicker. The nodular carbon was unaffected by this treatment ; it did not regain its rotundity as is noted in Fig. 9. The tensile strength of this bar was 27·3 tons per sq. in., a reduction of 9 tons. The structure shows that such bars are in a condition for further hot or cold work.

Bar No. 3.—Four passes, annealed, and a further four passes. This rolled very easily but the final pass was conducted at a temperature well below the critical range. The tensile strength of this bar was 39·1 tons sq. in. The peculiarity of the structure now is that the ferrite is ground down intimately among the carbide and the nodular carbon comes to the surface of the bar. This occurs in the centre of the bar but the outer area is also affected only to a lesser degree, Figs. 10 and 11. When these bars are annealed by reheating to 925° C. and cooled on the floor, the ferrite and pearlite are restored to a fine degree,but the nodular carbon remains the same elongated structure, Figs. 12 and 13.

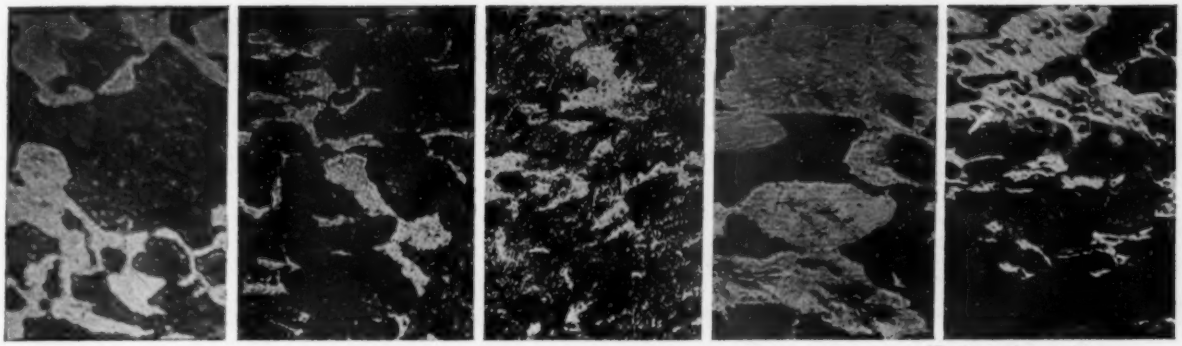
Bar No. 4.—As this was ruined no micrograph was prepared, but the outside cracks were at least $\frac{1}{2}$ in. in depth (Fig. 5).

Bar No. 6.—Four passes, annealed, four more and a further three without intermediate anneal. This specimen was ruined because it parted in two, but the microscope revealed that the graphite had elongated into very thin slits and apparently one of these, forced to the outside, Fig. 16, had started the crack as it engaged the rolls, from which it emerged neatly cut into two parts. A heat-treatment would have prevented this. Saturated pearlitic iron is difficult to roll cold. The ferrite being crushed down and forcing pearlite to the surface results in a great hardening of the metal. It was impossible to saw or machine test bars from this heavily drawn iron. The thickness of the bar was reduced to less than $\frac{1}{2}$ in. and apparently when the graphite reaches the surface it drops out without injury to the bar ; small elongated zones were noted where this had happened. Figs. 14, 15 and 16 reveal the condition of the bars at the surface.

There is no doubt that uses will be found for this material, because it can be annealed between the passes when it becomes too hard, and the reductions can be made to whatever size or shape is required. It can be cut with shears mechanically, if required, and offers possibilities for the application of malleable iron castings, part of which can be subsequently forged.

High Silicon Malleable Cast Iron.

Experiments were next conducted upon a high silicon malleable (0·80%) which showed signs of primary graphite deposition as cast. It gave no trouble when being rolled, but it resisted all attempts to straighten and broke off short with a grey slitted macrostructure as shown in Fig. 17. Surface microexamination showed that ferrite is more plentiful on the outside but proceeds to a dense



All micrograph are ×100.

Figs. 18, 19 and 20.—Longitudinal sections show that ferrite is more plentiful at outside, becoming less towards centre, until the true whiteheart malleable ceases and grey iron is apparent.

Fig. 21.—Showing graphite centre : note spaces where it was deposited.

Fig. 22.—Structure at edge of bar : coarser ferrite is formed at the centre, and the graphite splits up.

mass of emulsive, distorted pearlite as the centre is approached, as in Figs. 18, 19 and 20.

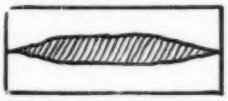


Fig. 17.—Effect of primary graphite in rolled malleable cast iron.

The cross-section shows that such irons would be useless. The graphite rolls out, finally splits up into tiny fragments and leaves a cavity line not unlike peeling. This, of course, weakens the metal but it appears to suggest that only the true malleable rolls out. The change from this to the grey section is abrupt, and the ferrite does not roll out. In Figs. 21 and 22 the tiny fissures, which have extruded their primary graphite, can be plainly seen. Large tracts of ferrite are seen in the centre but the flaky graphite has disintegrated completely leaving a series of "dots" of carbon running after each other. Apparently the grey centre with its weakness is protected by being surrounded by true malleable metal during the rolling operation, but it has lost its malleability and is useless as such.

Summary of Results

Briefly stated the conclusions reached, show that hot work on malleable cast iron increases strength and hardness ; refines the grain ; produces homogeneity to a large extent ; elongates the nodular carbon ; primary graphite carbon destroys the intrinsic properties of the material, since it does not roll out ; overheated malleable is unsuitable for rolling on account of the re-formation of free cementite ; apparently the material must be treated in a similar manner as steel ; the initial work must not be applied too heavily.

The results of these experiments show that malleable cast iron can be hot worked by rolling or forging, and cold worked to a degree where annealing or softening is required if further work is required to be sone. Such work results in an enhanced tensile strength with much higher Brinell number, but with consequent reduction in ductility.

On the Testing of Magnet Steels

IT is usual to judge magnet steels according to the product of their residual magnetism and their coercive force, both expressed in their international units. These are between 7,000 to 10,000 Gauss and 60 to 800 Oersted, respectively—i.e , the influence of the coercive force on the fluctuations of the coefficient of quality is much greater than that of the residual magnetism The testing instruments, based on these relations, are very complicated. The report shows that nearly all tests of permanent magnet steels can be carried out quickly and accurately by very simple means.

The determination of residual magnetism and coercive force can be replaced by the determination of those values of magnetic induction and magnetic field strength, which give the maximum value of their product. Another consideration leads to the conclusion that the testing of magnet steels must be possible on test-pieces of any square section, without special machining of these pieces.

Based on considerations of the behaviour of permanent magnets and the curve of demagnetisation, the determination of this curve by means of rod-shaped magnets is explained. Specimens of different magnet steels in different states of treatment have been used. A cross-section has been taken, $0{\cdot}75 \times 1{\cdot}50$ cm., the qualities being one tungsten magnet steel and four cobalt magnet steels with 7, 10, 15 and 35% cobalt respectively. Five test pieces of each quality have been produced, with lengths based on the above-mentioned theoretical considerations. For each piece the apparent residual induction has been measured, after magnetisation in a field of 4,000 Oersted, by drawing off an induction coil from the centre of the test-piece, and the demagnetisation field is determined by quick removal of the voltmeter from the centre of the test-piece to a position practically outside of the influence of the field. These are comparatively simple measurements.

The result of the investigation may be summarised as follows : Combining the figures of several test-pieces with different length-to-diameter ratios the curve of demagnetisation of magnetically soft specimens can be determined. As the demagnetisation factor depends on the permeability of the material, this method is, however, not applicable to magnet steels. Using magnetic voltmeters, the demagnetising field of magnet steels can also be measured. It has been found that a voltmeter whose range would just be sufficient for the testing of a rod of a length of two-thirds that of the shortest test-piece, could be used for this purpose without significant error. The alterations of the field strength of magnet steels, owing to the dependence of the demagnetisation factor of bar-shaped specimens on the quality of material, are determined by measurements with the voltmeter. They are considerable, but can be taken into account easily by graphic methods. Thereby also the curve of demagnetisation of magnet steels can be determined by drawing off an induction coil connected with a ballistic galvanometer from rods of different lengths. The accuracy of the method is sufficient for all measurements necessary in practice.

It is proposed for a general testing of magnet steels to determine only the induction and the field strength corresponding to the maximum of energy content per cubic-centimeter of material.

Mitteilungen aus den Kaiser-Wilhelm-Institut für Eisenforschung. Dusseldorf. Vol. XIX. No. 6. Heinrich Lange. Price, RM2·00.

Cartellisation in the World Aluminium Industry Part II.

By Robert J. Anderson, D.Sc.

The disparity between the extensive possibilities of production and the limited possibilities of consumption has long presented an economic problem, and the cartel movement is an effort to control producing and marketing activities. This article reviews the first, second and part of the third international cartels, and indicates how rapidly the aluminium industry has progressed.

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First International Aluminium Cartel

THE first international cartel in the aluminium industry was formed in 1901. Declining prices, poor sales, increasing competition, and the unsatisfactory outlook at that time were some of the conditions which impelled the producers of primary metal to establish this organisation. In 1901 practically all output of aluminium was produced by the following five companies: Aluminium-Industrie A.-G., Switzerland; Cie de Produits Chimiques d'Alais et de la Camargue, France; Société Electrométallurgique Française, France; the British Aluminium Co., Ltd., United Kingdom; and the Pittsburgh Reduction Co., United States. It has been stated[2] that these five companies were members of the first international aluminium cartel. Evidently, however, the Pittsburgh Reduction Co. was associated rather loosely with the organisation, and maintained relations through its subsidiary firm, the Northern Aluminium Co., Ltd., Canada.

Among other provisions, the cartel agreement stipulated the fixing of minimum prices, allocation of quotas and sales territories, and uniform conditions of delivery and payment. These applied as among the European producers. It has been claimed that the Pittsburgh Reduction Co. was a party regarding the division of markets, but not the price-fixing (*cf.* "Second International Aluminium Cartel," below). Sales quotas were apportioned to the cartel members on the basis of output previously made. The American market was supposed to be allotted exclusively to the Pittsburgh Reduction Co., its quota for the European market being supplied through the cartel and not directly to consumers. The business affairs of the organisation were managed by the Aluminium-Industrie A.-G. at Neuhausen, Switzerland. When the cartel was formed this company was the largest producer of aluminium in Europe. Table I. may be noted in this connection. It gives the output by countries for the years just before the formation and dissolution of the cartel. Renewal of the first agreement was effected by the producers in 1906, but late in 1908 the cartel was dissolved. During most of the period 1901-1908 the five companies above listed held practically a world monopoly of primary aluminium.

TABLE I.

WORLD OUTPUT OF PRIMARY ALUMINIUM AS RELATED TO THE FIRST CARTEL.

Figures in Metric Tons.

Country.	Year. 1900.	Year. 1907.
France	1,000	6,000
Switzerland (*a*)	2,500	4,000
United Kingdom	600	1,800
United States	3,200	8,000 (*b*)
World totals	7,300	19,800

(*a*) Includes output in Austria-Hungary and Germany.
(*b*) Includes output in Canada.

It is of interest now to consider the course of prices during the existence of the cartel. In the following remarks the prices given are the yearly averages. These varied appreciably as among the several countries. In 1901, when the cartel was formed, the price of primary aluminium in Switzerland was 2.5 Swiss francs a kilogram. It was 2·95 francs during the next three years, 4·35 francs in 1905 and 1906, and 4·5 francs in 1907. With outside competition arising and general price cutting, it broke to 2·05 francs in 1908 and declined further to 1·45 francs in 1911. The highest minimum price fixed by the cartel was 2·75 francs. In Germany the price rose from 2 marks a kilogram in 1901 to 3·6 marks in 1907, and then fell to 1·65 marks in 1908. In the United States the price advanced from 33 cents a lb. in 1901 to 45 cents in 1907, and then dropped sharply to 28·7 cents in 1908. During this period the duty on aluminium pig imported into the United States was 8 cents a lb.

The price policy of the cartel was severely criticised by consumers and others, especially during the late years of its existence. Claims were then made that the price was immoderately high and the policy extortionate. In this connection it is pertinent to compare the price movements of aluminium and some other non-ferrous metals in the European and American markets during the period 1901-1907.

Referring to the yearly averages in New York and the low-to-high movements during this period, the following figures show the approximate advances in prices of the several non-ferrous metals: Aluminium, 36%; electrolytic copper, 72%; lead, 39%; tin, 50%; and zinc, 52%. In Europe the aluminium price increased 80%, as based on Swiss and German quotations. With reference to the London market the following figures show the approximate advances in prices: Best selected copper, 66%; lead, 74%; tin, 53%; and zinc, 59%.

Prices of non-ferrous metals declined abruptly after the onset of the business depression in 1907. It is worth while here to note the relative movements. The following figures show the approximate decreases in prices as measured by the differences between the maxima attained during the period 1901-1907 and the averages for 1908, with reference to the New York quotations: Aluminium, 36%; electrolytic copper, 34%; lead, 26%; tin, 27%; and zinc, 24%. In Europe the decrease in the aluminium price was about 54%. With reference to the London market, the approximate decreases were as follows: Best selected copper, 32%; lead, 31%; tin, 21%; and zinc, 26%.

The evidence is that the advance in aluminium prices to the high level of 1907 was not due mainly to cartel policy. In fact, as an element, this was considerably less important than the general economic situation. The price of commodities naturally moved higher with the increasing demand which accompanied the upswing of the business cycle, and that of aluminium would have advanced without cartel influence. In the United States the percentage increase in the price of aluminium was considerably less than that of most other non-ferrous metals. In Europe, however, this percentage increase was appreciably more. But for most metals the advance of prices was greater in Europe than in the United States. One policy of the first cartel was to raise prices to remunerative levels. The object was sought by fixing minimum prices. Under this condition stability of prices could not be expected.

2 Nots, W. F. "Representative International Cartels, Combines and Trusts, 1929." U.S. Bur. For. and Dom. Commerce, Trade Promotion Series No. 81. Washington. 76 pp.

As already indicated, the first international aluminium cartel lasted about eight years. It was dissolved on September 30, 1908. The disruption has been ascribed to various causes, but was undoubtedly due to a combination of circumstances. Among other factors, internal disputes and the rise of outside competition were the most adverse to further maintenance of the cartel agreement at that time. Still, the cartel as organised contained certain elements of weakness, and its downfall was also related to some other causes.

Concerning the rise of outside competition, it may be said that the basic patents covering aluminium production by the Hall-Héroult process expired over the period 1906-1909. Most of these patents were owned by one or another of the companies associated in the cartel, or the process was used under exclusive licence. About 1905, interests outside the cartel were attracted to the aluminium business in Europe by the approaching expiration of the Héroult patents and by the high level of prices for the metal. These interests built works, and the cartel members also expanded their productive capacity. As a result much new plant came into operation in 1907 and 1908, and plans for additional output had been projected. The outside companies began to offer aluminium at prices slightly less than those quoted by cartel members. Then price-cutting broke out, and the cartel finally reduced its minimum price to 1·75 Swiss francs a kilogram. The situation became worse as the demand for aluminium slackened with the continuation of the business depression dating from the so-called rich man's panic of 1907 in the United States. Also, displacement of influence in the cartel, due mainly to the growing power of the two French companies, and more internal rivalry were factors which weakened the solidarity of its organisation.

After the cartel was dissolved, aluminium prices were depressed to low levels in the competition for business. In Europe the average for 1911 represents the all-time yearly low. So far, the average for 1914 is the lowest reached in the United States. The average price of aluminium in Switzerland for 1911 was 1·45 Swiss francs a kilogram. In the same year it was 1·15 marks in Germany. This figure corresponds to about 12·2 cents a lb. The average price in the United States for 1911 was 20·07 cents, or about the same as the European price plus the American import duty of 8 cents.

Final collapse of the first international aluminium cartel was due in part to circumstances over which it had no control and in part to situations of its own making. A different policy might have helped to preserve the organisation, but it would probably have failed anyway under the complex of conditions encountered.

Second International Aluminium Cartel

Efforts were made in 1901-1911 to form a new international cartel in the primary aluminium industry, but were unsuccessful. These failed mainly because the producers could not come to agreement concerning quotas of output. Certain temporary arrangements for marketing were in effect, however, among some aluminium companies during this period. At length, negotiations led to agreement among the principal producers, and a new cartel was formed in 1912. This is referred to here as the second international aluminium cartel. Like the first organisation, it was generally known in Europe as the International Aluminium Syndicate. The same financial interests were represented in the first and second cartels. Members of the second cartel included the following companies: Aluminium-Industrie A.-G., Switzerland; L'Aluminium Français, France; the British Aluminium Co., Ltd., United Kingdom; and the Northern Aluminium Co., Ltd., Canada.

Before the second international cartel was formed, a national syndicate was organised by the French producers to manage all sales of primary aluminium and regulate output in France. While one object of this organisation was to divide the French market (protected by a high import duty) among the home producers, another object was to establish a joint agency whereby the French companies could present a united front in negotiations with the leading foreign producers. It was recognised at this time that national cartellisation of the French industry was necessary, or that its control had to be concentrated, before a new international cartel could be formed on a sound basis. As a result of this situation, the company known as L'Aluminium Français was founded in 1911. It represented the French interests in the second international cartel. This company still handles the sale of primary aluminium produced in France, but its activities have since been extended to various other branches of the industry.

The Northern Aluminium Co., Ltd., was the Canadian firm owned by the Pittsburgh Reduction Co. On January 1, 1907, the name of the latter was changed to Aluminium Company of America.

In an interval before the first cartel collapsed and the second was organised, a number of "outsiders" began to produce aluminium. But shortly, most of these were merged with, or their control was acquired by, companies which were members of the first cartel. Among the so-called outsiders were included established concerns (engaged in the manufacture of heavy chemicals, for example) which undertook aluminium production for the first time during this interval, and also new firms organised for that particular purpose. The principal new producers of this period are mentioned in the following brief statement:—

In Italy the construction of an aluminium plant was started in 1906 by the Società Anonima per la Fabbricazione dell 'Alluminio. In France the Société des Forces Motrices et Usines de l'Arve (established in 1895) entered the aluminium industry in 1906. In the same year the Société des Produits Electrochimiques et Métallurgiques des Pyrénées was formed and started production. Also in 1906 the Aluminium du Sud-Ouest and the Electro-Métallurgie du Sud-Est were organised; the latter was a subsidiary company of the former. In the United Kingdom the Aluminium Corp., Ltd., was founded in 1907 and soon began to produce metal. And in that year the Anglo-Norwegian Aluminium Co., Ltd., was organised for production in Norway; the operating company there was called A/S Vigelands Brug. In Switzerland the Fabrique d'Aluminium Martigny S.-A. began to produce aluminium in 1910. At present the Aluminium Corp., Ltd., is controlled by the Alliance Aluminium Holdings, Ltd. (see Alliance Aluminium Cie., A.-G., below). Excluding the Fabrique d'Aluminium Martigny S.-A., the other companies have been merged or liquidated.

World output of primary aluminium in 1912 was about 63,000 metric tons or nearly 3½ times that in 1908. Of total output in the respective years about 44% and 32% were produced by the Aluminium Company and its Canadian subsidiary firm, and the rest by the European companies. Members of the first cartel had considerably increased their plant capacity during 1905-1910, and works built by new producers had come into operation as already mentioned.

The second international aluminium cartel was similar in type to the first, and the objects of both were the same. In the first cartel, however, prices were fixed mainly by independent action of the Aluminium-Industrie A.-G., but in the second organisation prices were determined by joint agreement of the members. Output was regulated on a quota basis, settled by the sales made during a preceding period. The method of sales control was similar in both cartels, as was the division of markets. Meetings were held by members of the second cartel at Paris from time to time, when prices were fixed and output regulated. The range of average yearly prices for primary aluminium during the period 1912-1914 (up to the outbreak of the world war) was as follows: In Switzerland, 1·85–2·1 Swiss francs a kilogram; in Germany, 1·5–1·7 marks a kilogram; and in the United States 18·63–23·64 cents a lb. No

attempt was made by the second cartel to raise prices to high levels. The cartel functioned until the war started, and its activities then came to an end.

A so-called war cartel existed during the years 1915-1918, under agreement of aluminium producers in the European allied countries. This was concerned mainly with supplying the military needs of the allied powers during the world war.[3]

In passing, it may be remarked that an aluminium purchasing association was established in Europe by large consumers, chiefly German, in order to oppose the second cartel. The outbreak of the war terminated this association.

Just before the first cartel was dissolved an agreement was entered into (as of September 25, 1908) between the Aluminium-Industrie A.-G. and the Northern Aluminium Co., Ltd. Among other provisions this stipulated a division of markets in respect of Europe, the United States and Canada, and the rest of the world. Sales in the United States were reserved exclusively to the Aluminium Company of America. This division of markets was abrogated under the Consent Decree of 1912 (United States of America vs. Aluminium Co. of America, U.S. District Court, Western District of Pennsylvania).

Third International Aluminium Cartel

After the Armistice in 1918 conversations were held among European aluminium producers over a period of several years, with the view to forming a new international organisation. General conditions were favourable to cartellisation about this time. For example, large stocks of metal had been accumulated as a result of the war, and prices dropped sharply when those fixed by the various warring countries were abolished. Moreover, the productive capacity was far out of line with demand during the post-war industrial depression. The producers could not, however, come to an understanding until 1923. Then the first post-war agreement, limited to prices, was effected. Further conversations finally led to the formation of a new international organisation in the late summer of 1926. This is referred to here as the third international aluminium cartel. The organisation was originally established for a period of about two years, but the agreement was renewed in 1928 for three more years until December 31, 1931.

TABLE II.

WORLD OUTPUT OF PRIMARY ALUMINIUM (*a*) AS RELATED TO THE SECOND AND THIRD CARTELS.

Figures in metric tons.

Country.	Year. 1913.		1927.
Austria	3,000 (*b*)	..	4,000
Canada	5,900	..	38,500
France	14,500	..	25,000
Germany	1,000	..	28,400
Italy	900	..	2,500
Norway	1,500	..	20,800
Switzerland	10,000	..	20,000
United Kingdom	7,600	..	7,900
United States	20,900	..	74,200
World totals	65,300	..	221,300

(*a*) Statistische Zusammenstellungen, Metallgesellschaft A.-G.
(*b*) Austria-Hungary.

The members of the third cartel included Aluminium-industrie A.-G., L'Aluminium Français, the British Aluminium Co., Ltd., and the Vereinigte Aluminium-Werke A.-G. Control of world capacity for aluminium production in 1926 was divided about equally between the cartel membership (and affiliated concerns) and the Aluminium Co. of America (with its subsidiary firms). Small producers of aluminium in Austria, Italy, and elsewhere, as well as the Aluminium Co. of America and its controlled producing organisations outside the United States did not join the cartel. It has been suggested, however, that agreements existed between the cartel and some non-member companies in respect of prices for aluminium pig. Meetings of the third international cartel were held at Paris. Table II. gives the world output of primary aluminium by countries for 1913 and 1927, one year after the second and third cartels, respectively, were established. These figures may be compared with those in Table I., which show the rise of output over the approximate duration of the first cartel.

World output of primary aluminium increased about three and a half-fold over the period between the collapse of the second cartel and the time when the third organisation was established. This interval is marked by the appearance of new producers, further expansion of capacity by the old companies, and additional mergers. A summary of the development from 1914 through 1931 (the year when the third cartel was reorganised) is given below.

In France the Cie de Produits Chimiques d'Alais et de la Camargue merged in 1914 with the Société des Produits Electrochimiques et Métallurgiques des Pyrénées, and in 1916 with the Société des Forces Motrices et Usines de l'Arve. And in 1921 the first-mentioned firm combined with the Société Electrométallurgique Française. The new company took the name Cie de Produits Chimiques et Electrométallurgiques Alais, Froges et Camargue. This concern and the Société d'Electrochimie, d'Electrométallurgie et des Aciériés Electriques d'Ugine currently control all aluminium-producing works in France. The latter company is an outgrowth of the Société d'Electrochimie, founded in 1889 to make chemical products. In subsequent years it merged with several firms, including the Société La Volta and the Société Electrochimique du Giffre, and in 1922 with the Aciériés Electriques Paul Girod d'Ugine. Previously, the plant of the Electro-Metallurgie du Sud-Est had been acquired by the Girod concern. Unlike most large producers of aluminium the two French companies manufacture numerous other products, especially chemicals and ferro-alloys. French capacity for aluminium output was considerably enlarged in 1924-1926. The Cie de Produits Chimiques d'Alais et de la Camargue formed the Southern Aluminium Co. and began to construct a reduction works in 1914 at Whitney, North Carolina. This plant was sold in 1915 to the Aluminium Company of America.

In 1912 the Société Générale des Nitrures and Det Norske Aktieselskab for Elektrokemisk Industri founded Det Norske Nitrid A/S with the object of exploiting the Serpek process. This proved to be impractical, and the latter company soon undertook the production of aluminium. Reduction works were built in Norway in 1914 and 1916, and subsequently their capacities were about doubled. At present, Det Norske Nitrid A/S is owned jointly by Aluminium, Ltd., Cie de Produits Chimiques et Electrométallurgiques Alais, Froges et Camargue, and the British Aluminium Co., Ltd. Also, in Norway, the Norsk Aluminium Co. was formed with home capital and began to build a plant in 1916. After the war the Aluminium Co. of America bought an interest in this Norwegian firm, and it is now controlled by Aluminium, Ltd. Then the A/S Haugvik Smelteverk, a subsidiary company of the Aluminium Corp., Ltd., built a plant in Norway and began to produce metal in 1928.

Before the war primary aluminium was produced in Germany only at one small plant owned by the Aluminium-Industrie A.-G., but considerable quantities were imported as raw material for the manufacture of finished wares. Soon after the war began, German supplies of various metals declined rapidly because imports were either cut off or much restricted, and demands for both military and other purposes increased greatly. But bauxite was obtainable in the then Austro-Hungarian Empire. So construction of several aluminium-reduction works was shortly started in Germany with governmental co-operation or financial participation.

3 Pitaval, L. "Les Ententes dans l'Industrie Mondiale de l'Aluminium." *Jour. Four. Elect.*, vol. 46, 1937. Pp. 83–85.

Reviews of Current Literature

Copper in Cast Steel and Iron

THE extension of quantity production methods in the foundry industry has stimulated research in regard to the production of iron and steel castings. One result has been the establishment of copper as an alloying element for steel and iron. Copper is relatively cheap, reduces foundry costs by its beneficial effects on fluidity and heat-treatment and, in many cases, additions facilitate and therefore cheapen machining.

In this book the results of recent research on the influence of copper in the casting of steel and iron are clearly summarised, and details are given of the uses to which copper is being put, and to which it can be put, in modern foundry practice. It shows how the mechanical properties of cast steel are improved by the addition of between 1% and 3% Cu; the improvement in yield point and tensile strength independent of the carbon content of the steel, this being of the order of 16 tons per sq. in. for approximately 2·5% Cu addition.

The effect on ductility and impact resistance is explained, proving that for a given tensile strength a copper steel is tougher and more ductile than a plain carbon steel. Other factors concerning cast copper steels are their susceptibility to precipitation hardening, improvement in mechanical properties (especially when copper is used in conjunction with the cheaper alloys such as Mn, Cr, and Si); how copper additions increase the fluidity of cast steels—up to 3·5% may be added to facilitate running intricate castings—interesting details, and illustrations are provided of copper used with high carbon steels for automobile crankshafts to accelerate annealing, improve both tensile and fatigue properties and promote fluidity; to increase corrosion resistance; and to improve both corrosion resistance and mechanical properties in some classes of stainless steels.

The influence of copper in iron is dealt with separately for malleable and cast irons, and it shows how additions of about 1·5% copper will permit considerable reduction in the annealing cycle of blackheart malleable iron result in a substantial increase in tensile properties and toughness and virtually eliminate any tendency to galvanising embrittlement. It is further shown that copper malleable iron is susceptible to age hardening, as is also the case with copper cast steel.

Research indicates that equally beneficial results may be expected in the case of whiteheart malleable iron.

The effect of copper in cast iron is analysed at length. Copper acts as a graphitiser in grey iron, refining the graphite whilst strengthening and toughening the matrix. It will be evident that this combination of qualities makes copper a very desirable addition to castings for such applications as motor-cylinders or pressure, as it prevents light sections from chilling, but holds a close structure in heavy castings.

Copper can be used to replace part of the silicon content, in which case it produces a marked increase in the mechanical properties of the cast iron, promotes uniformity of structure, and damps out the effect of small changes of composition such as may occur during a daily run—a useful stabilising influence in light repetition work where chill needs accurate control.

Hardening alloys such as manganese, chromium and molybdenum, commonly added to high-duty cast irons, tend to have a chilling effect and may tend to make the iron both brittle and difficult to machine. How this possible chilling effect and embrittlement is balanced by the addition of copper is explained very fully.

The addition of around 7% copper in conjunction with nickel and chromium is shown to be beneficial in corrosion-resisting and heat-resisting austenitic irons, and a further point of considerable interest that is dealt with is that complete graphite refinement is obtainable in ordinary grey irons by the adoption of high copper additions, say, 6 to 8%.

The book is well indexed, has a useful list of references and is excellently illustrated with photographs and diagrams. One of the most valuable features is the provision of tables of compositions and properties, hardness conversion tables and another table giving the cost of copper additions to steel and iron showing this cost in terms of price per ton of castings produced (from 1% to 5% addition), and based upon the cost of scrap copper per ton from £30 to £80. A very interesting comparison between the cost of using copper and other elements as alloying factors is also included in tabular form.

This is a book which can be recommended as being of equal value to the engineer, the metallurgist and the student.

Publication No. 29 of the Copper Development Association, Thames House, Millbank, London, S.W. 1.

Metallography

PREVIOUS editions of this valuable work by Dr. Desch are well known, but, so much progress has been made in the scientific study of metals and alloys, since the last edition appeared, that drastic revision of the whole work and the complete rewriting of many of the chapters has been necessary for this, the fourth, edition. Among the subjects treated are the improved technique of thermal analysis and of microscopical examination, use of the experimental methods of determining metallic structures, and a theoretical outline of their interpretations, the changes proceeding in solid alloys, including age-hardening and the relations between ordered and disordered solid solutions, and the processes of mechanical deformation. All these subjects are discussed in the light of modern physical and chemical knowledge.

This book provides a general introduction to the subject in a form which is admirably applicable to the needs of the physical chemist approaching the study of metals and also to those of the practical metallurgist wishing to know the modern methods of investigating technical alloys. The author discusses in detail a number of topics of special scientific interest, thus, for instance, the process of age-hardening, which is now known to be characteristic of a very large number of alloys. The author discusses age-hardening in the light of research on the phenomenon and concludes that two processes are involved, one being the formation, and the other the growth, of nuclei within a solid solution. This is also true of the disorder—order change, which has already lent itself to theoretical treatment, and it is certain that the same methods may be applied with advantage, and that a quantitative study of age-hardening systems, taking into account the change of energy involved in the change of place among atoms on a lattice, will prove fruitful.

Although thermal and microscopical analyses remain the foundation of metallographic study, the new knowledge obtained by the use of X-ray methods is so extensive and so important, that the author has considered it essential to include an account of the principles of X-ray analysis and of the experimental methods which may be employed in a metallographic laboratory. Two chapters on the subject have been specially written by Mr. G. D. Preston, M.A., who deals theoretically and experimentally with the method of crystal analysis by means of X-rays.

The book is complete with very extensive references to the literature of metallography, including an author's index, and a useful subject index. The general arrangement and the presentation of the subject matter is admirably suited to metallurgical students, and as a standard work on metallography it will be regarded as an invaluable introduction to an engrossing subject.

By CECIL H. DESCH, D.Sc., Ph.D., F.R.S., Published by Longmans, Green and Co., Ltd., 39, Paternoster Row, London, E.C. 4. Price 21s. net.

High-temperature Welding Flames

THIS is a very scientific book on the subject of flame temperature for welding purposes, with a definite practical application. Complete investigation of flame behaviour, apart from the direct pyrometrical measurement of temperatures, is a long and laborious procedure, but current data on gases at high temperatures enables calculations to be made concerning flame temperatures and the chemical composition of flames with sufficient accuracy, such calculations being based on knowledge of specific heats and with particular reference to the dis-association constants of the constituents of the flames, as for example, the dis-association of molecular hydrogen into atomic hydrogen.

Spectroscopy has furnished sufficient reliable data during the past ten years to enable this problem to be dealt with.

The author discusses the various physical constants essential for such calculations, outlines the method of thermodynamical calculation from these constants of the temperature of a very hot flame, and gives curves showing this temperature as a function of the composition of the initial mixture.

The first chapter deals with specific heats of gases at high temperatures, discusses the application of the classical and modern theories ; the second chapter is devoted to consideration of dis-association constants for flame constituents ; and the third and final chapter is concerned with the principles of the thermodynamic calculation of flame temperature, dealing with the oxy-acetylene flame and the influence of an excess of oxygen ; the investigation of atomic hydrogen and of the oxy-hydrogen flame ; calculation of flame temperature for oxygen-methane and oxygen-butane flames.

The book also outlines a new method for the determination of flame temperatures—taking the oxy-acetylene flame as example—and considers the oxy-acetylene flame as a photometric standard.

Results and conclusions are summarised, and a useful bibliography is appended. The work has been translated by N. F. Daniel, B.Sc., A.I.C.

By D. SÉFÉRIAN (Dr. of Science at the University of Paris, Civil Mines Eng. ; and Professor at l'École Supérieure de Soudure Autogène), and published by the Penton Publishing Co., Ltd., Caxton House, London, S.W. 1. Price, 3s. 9d. net.

Symposium on Corrosion Testing Procedures

THIS book compiled by the American Society for Testing Materials has the valuable feature that extensive discussion of the seven technical papers which were presented by 12 authorities at the 1937 regional and annual meetings of the society, is included. Nearly one-quarter of the book is devoted to discussion, making available the opinions of leading engineers and technologists.

The papers cover principles of corrosion-testing (the first including a most useful table which gives a comprehensive survey of the whole range of corrosion testing) ; atmospheric and salt-spray testing are described in detail, and there is a valuable description of an electrical-resistance method of determining corrosion rates. There are papers on corrosion-testing methods for copper alloys ; standardising liquid corrosion testing, and a very extensive discussion of soil corrosion testing over a wide range of media. It is noteworthy that each of the contributions was reviewed by a special committee, and the Symposium includes authoritative data which should be of considerable interest to all concerned with metallic minerals.

The nine factors which are considered in the effect of changes in environment on the distribution and intensity of corrosion are : oxygen concentration, hydrogen ion concentration, conductivity, velocity of liquid, temperature, composition of the corroding medium, concentration of the corroding medium, particle size, and humidity.

Copies of this publication can be obtained from the American Society for Testing Materials, at their Headquarters, 260, S. Broad Street, Philadelphia ; the price being $1.25 per copy with heavy paper cover, or $1·50 with cloth binding.

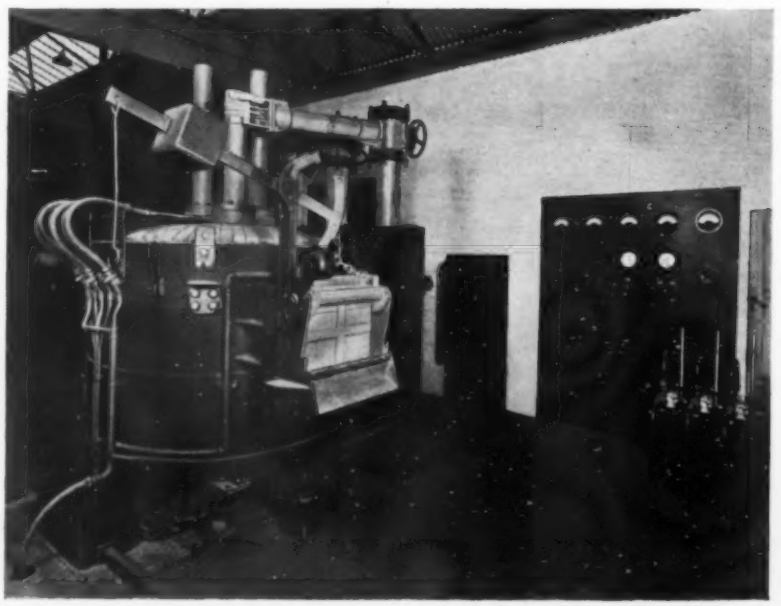
Electrical Heating Equipment

THERE has been a continuous demand for induction furnaces during 1937, so that in this country to-day the installed capacity of this type of unit exceeds 11,500 kw. A large proportion of this equipment was manufactured in the Trafford Park Works of Metropolitan Vickers Ltd. Progress has been made in details tending to increase the reliability of these furnaces and the protection of the operators. Improvements in tilting arrangements have been made which add to the convenience of pouring. The advantage of setting up two furnace emplacements with a change-over switch connected to one generator was shown by a Sheffield steelworks recently, when they cast an 11-ton ingot of special steel from their two five-ton furnaces.

For laboratory work the valve-operated furnace is proving a valuable development, and two equipments, each capable of melting 1 lb. of steel, are on order by the latter firm. In conjunction with a high vacuum pumping plant small quantities of steel can be melted *in vacuo* for research purposes.

A recent interesting installation by the General Electric Co. Ltd., is a 12/15-cwt. electric arc furnace in the works of Johnson Matthey and Co., Ltd. (Brimsdown) for the melting of nickel alloys. Special furnaces have also been produced by this company for the bright annealing of small steel and iron parts having magnetic properties, and the continuous bright annealing of steel strip in lengths.

A 15 kw. G.E.C.-Brown-Boveri arc furnace, 300 kva. for melting nickel metal.



Chromium-Manganese Steels as Heat-Resisting Steels

By J. H. G. MONYPENNY, F.Inst.P.

The first part of this article was devoted to a study of the important structural changes produced in chrome manganese steels of various compositions; in this part, the author gives a more detailed study of the steels in those ranges of composition which appear to have the necessary stability of structure.*

A STUDY of the structural changes produced in chromium-manganese steels by prolonged heating at temperatures between about 500° and 900° C., and described in the first part of this article, indicates that only steels lying within certain rather narrow ranges of composition appear to be suitable for practical use as heat-resisting steels. In the first place, there seems to be no advantage in adding less than about 10% manganese. Such additions to steels containing up to about 15% chromium would appear to make the treatment and working of the steel more difficult. The austenite obtained in these steels is not stable against prolonged heating between 500° and 800° C., but, on the other hand, its breakdown first into martensite and later into sorbite takes place much more sluggishly than in steels relatively free from manganese but otherwise similar in composition. This sluggishness may be illustrated by the data obtained by Schmidt and Legat, and quoted in the first part of this article, where it was shown that a steel containing 0·08% C, 10·2% Cr and 7·5% Mn had a Brinell hardness value of about 400 after prolonged annealing at temperatures up to 700° C., the value falling to 260 after 30 hours at 850° C. This behaviour was probably due in part to the fact that the steel had previously been quenched from 1,100° C. in an endeavour to produce as much austenite as possible; it is likely that it would have been more amenable to tempering had it been hardened at a lower temperature, probably 950° C. or thereabouts.

On the other hand, there is the possibility that this extra sluggishness might perhaps be turned to useful account should it be accompanied by greater strength in this range of tempering temperature. It is well-known that the creep strength of chromium steels (in common with most non-austenitic steels) falls rapidly at about 500° C. The writer is not aware of any published data on the creep strength of chromium-manganese steels containing up to about 10% manganese, but if their resistance to tempering may be taken as suggesting that they are also equally sluggish in recrystallising after cold work and hence likely to have a higher creep strength than, for example, chromium steels in the same range of temperature, they may have a useful future. In this connection it may be noted that nine or ten years ago, Messrs. F. Krupp, A.-G., patented steels containing chromium, manganese and tungsten, claiming that these steels possessed high strength at elevated temperatures. The range of composition covered was considerable but special mention was made of steel containing 12 to 14% chromium, about 5% each of manganese and tungsten and about 0·5% carbon. Undoubtedly the tungsten addition would itself confer strength on the steel, but it is interesting to note that a chromium-manganese steel in this particular range of composition, which shows considerable sluggishness up to 700° C. in its structural changes, was chosen as the base to which tungsten was added.

At the other end of the scale, the use of the highly alloyed chromium-manganese steels, in which a considerable amount of the compound FeCr is formed on heating at medium temperatures, should be avoided in practice as they become particularly brittle owing to this structural change. Ample evidence of this was given in the first part of this article; it will therefore suffice to quote the remark of G. Riedrich who stated, in the discussion on the papers by Brühl and by Schmidt and Legat at Düsseldorf, that in his experience such alloys became so brittle as to break like glass with the least bending.

From the point of view of structural stability and also of strength at high temperatures, steels which consist wholly of austenite—or nearly so—seem most desirable. If carbon content is to be kept low, the maximum amount of chromium such steels may contain is about 15%; as a result, their useful resistance to oxidation when heated—which depends on chromium, manganese apparently not being helpful in this respect—is limited to temperatures not exceeding about 800° C., or 850° C. at the most. This restriction in the useful temperature range has led to attempts being made to use duplex steels containing about 20% chromium and with manganese limited to 8 or 10%, the latter maximum being necessary to keep the steel well clear of the range of composition in which the compound FeCr is readily formed. Schmidt and Legat made a study of the properties of these steels—both austenitic and duplex—to some of which they added, however, about 1% of nickel as a means of improving their stability and properties. The steels they investigated had the following compositions, steel D being included as representing a typical chromium-nickel heat-resisting steel widely used in practice.

Mark.	C.	Si.	Mn.	Cr.	Ni.
A	0·21	0·95	8·0	19·0	1·0
B	0·16	0·58	15·7	16·8	1·3
C	0·14	0·19	15·6	17·3	1·4
D	0·15	1·59	1·2	25·1	17·2
E	0·18	0·02	16·3	14·2	—

The temperature range producing embrittlement and the speed at which it occurred was determined on steels A-D, the test pieces being first quenched in water from 1,060 to 1,100° C. Preliminary tests, in which the samples were annealed for 50 hours at a series of temperatures gave the results plotted in Fig. 6, and these suggest that embrittlement occurs most rapidly at about 600° C. in the chromium-manganese steels, but at a much higher temperature—about 850°—in the chromium-nickel steel. Further tests at three selected temperatures were then carried out for periods up to 400 hours; the results, given in Table VI, show that the chromium-manganese steels lose their toughness rapidly on heating at 510° C. and undoubtedly would behave in a similar manner at still lower temperatures.

TABLE VI.
Effect of Prolonged Annealing, at Temperatures indicated on Impact Value.

Duration of Annealing, Hours.	Impact Value (mkg./cm²)°.											
	Steel A.			Steel B.			Steel C.			Steel D.		
	510°	710°	850°	510°	710°	850°	510°	710°	850°	510°	710°	850°
Unannealed	40	40	40	39	39	39	37	37	37	18	18	18
50	11·5	2·5	10·5	37	5	6	35	2·8	4·5	20·8	8·5	5·2
100	5·5	2·5	9·5	5	5	5·8	2·2	3	4·2	18·8	4·5	4·5
200	3·5	2·5	5·8	4·5	4·5	5	2·2	2	3·9	16·5	5·5	5·5
300	2·5	—	7	4·7	—	4·9	1·5	—	4·1	14·5	—	7
350	—	4·0	—	—	4·2	—	—	2·8	—	—	5·5	—
400	2·2	—	—	4·7	—	—	1·5	—	—	13	—	—

° For the convenience of those not familiar with the results of Charpy-Mesunger impact tests, the following approximately equivalent Izod values may be useful:—

Charpy (mkg./cm²)	2	..	4	..	8	..	12	..	16	..	24
Izod (ft.-lbs.)	5	..	10	..	30	..	55	..	75	..	100

* METALLURGIA, November, 1937, pp. 7–12.

At 850° C. there is a slight indication that the maximum effect is produced in 100–200 hours, and that some improvement in toughness might be obtained after much longer periods.

Tensile tests were also taken on samples of three of the steels after holding for 100 hours at 850° C. and the results—given in Table VII, together with impact values on the same specimens—indicate that the steels still possessed considerable ductility in spite of their low impact value.

TABLE VII.

Tensile and Impact Tests on Samples Annealed for 100 hours at 850° C.*

Steel.	Yield-point (Tons/in.²)	Tensile strength (Tons/in.²)	E.% (l=5d.)	R.A.%	Charpy Impact (Mkg./cm.²)
A	31	58	25	43	4·6
B	28	45	34	30	5·6
D	24	47	22	18	4·7

* The values in this table—and most of the others given in this article—have been extracted from diagrams in the original papers. The values for yield-point and tensile strength are given to the nearest ton per sq. in.

These experiments show that marked embrittlement occurs with all the steels including the chromium-nickel steel D and the last-named fact should be kept in mind in judging the probable value of the chromium-manganese steels in practice. Actually, steel D, though admittedly a well-known and frequently-used heat-resisting steel, is probably less rapidly embrittled than steels of the chrome - nickel - tungsten type, which are also standard commercial materials for heat-resisting purposes. The results given in Table VIII may be quoted in this respect and one may note the very short period of heating necessary to reduce the Izod value of this steel to a low figure.

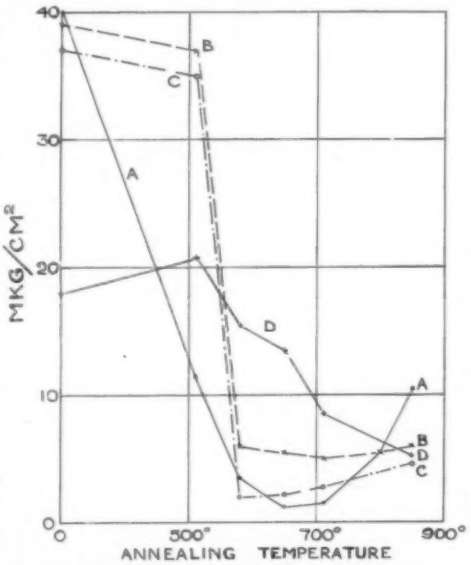


Fig. 6.—Effect of annealing temperature on impact value. Period of annealing, 50 hrs.

Steel.	C.	Si.	Mn.	Cr.	Ni.
A	0·21	0·95	8·0	19·0	1·0
B	0·16	0·58	15·7	16·8	1·3
C	0·14	0·19	15·6	17·3	1·4
D	0·15	1·59	1·2	25·1	17·2

Schmidt and Legat do not give details regarding the structures of steels A–E after quenching from 1,020° to 1,100° C.; it may be presumed however, that B and C would contain a small amount of ferrite, and A a distinctly larger quantity. They mention, however, that after annealing for 300 hours at 700 to 800° C., B and C undoubtedly showed the presence of the FeCr compound;

TABLE VIII.

C.	Si.	Cr.	Ni.	W.
0·35 ..	0·90 ..	22·2 ..	8·6 ..	2·6

Effect of Annealing at 850° C. on Impact Value.

Treatment.	Brinell Hardness No.	Izod Impact.
Softened 1,050° C.	207	57 ft.-lbs.
" " annealed 850° C. 2 hours	217	54 "
" " " " 4 "	228	36 "
" " " " 8 "	228	27 "
" " " " 16 "	255	12 "
" " " " 24 "	255	10 "

it is unfortunate that hardness data on these steels were not reported but the impact and tensile values given in Tables VI and VII suggest that the amount of the compound formed was not sufficient to make the steels dangerously brittle; the latter appear, in fact, to behave in a manner not greatly different from that of well-known heat-resisting steels of the chromium-nickel type, except that maximum embrittlement seems to occur at a lower temperature than with these widely used materials.

Schmidt and Legat also carried out tensile and impact tests at a series of temperatures between 500° and 900° C. on samples which had been annealed for a hundred hours at 850°. The tensile results do not call for much comment except that the values for tensile strength obtained at temperatures between 500° and 700° C. were markedly lower for the chromium-manganese steels A and B, than for the chromium-nickel steel D, the difference at 500° C. being about 20 kg./mm.² (about 13 tons/in.²). The impact values however, rose slowly with temperature as indicated in Table IX.

The probable effect of increasing the carbon content of chromium-manganese steels on their properties before and after prolonged annealing may be judged from data given by Brühl and relating to steels containing 15% manganese together with either 15% or 20% chromium. As a preliminary treatment, the samples were quenched in water from 1,200° C. (a temperature which seems unnecessarily high and likely to cause greater deterioration of the

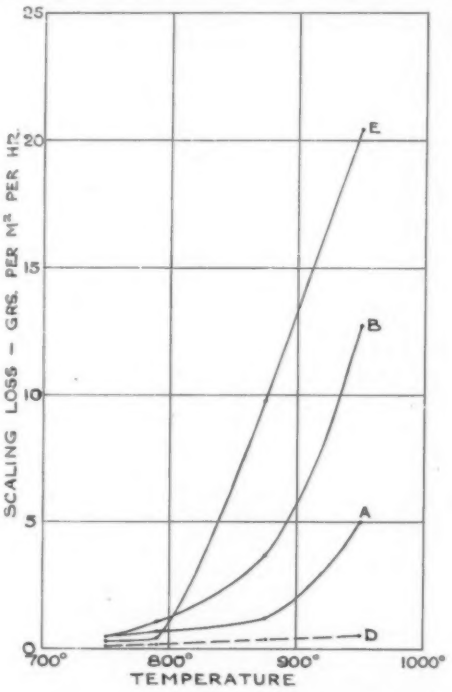


Figure 7.—Loss in weight by scaling produced by 72 hours heating in air at the temperatures indicated.

Steel.	C.	Si.	Mn.	Cr.	Ni.
A	0·21	0·95	8·0	19·0	1·0
B	0·16	0·58	15·7	16·8	1·3
D	0·15	1·59	1·2	25·1	17·2
E	0·18	0·02	16·3	14·2	—

mechanical properties during subsequent annealing than if a lower softening temperature were used) and were then held at 700° C. for 16 hours. The properties of the 15%

TABLE IX.

Impact Values at High Temperatures of Samples previously annealed for 100 hours at 850° C.

Testing Temperature.	Impact Value (Mkg./cm.²)		
	Steel A.	Steel B.	Steel D.
15° C.	4·6	5·7	4·7
500°	7·0	5·9	6·9
600°	7·1	6·5	7·1
700°	6·4	6·4	—
800°	7·1	6·9	8·1
900°	11·0	9·7	10·5

chromium steels, before and after this annealing are summarised in Table X and one may note that the lowest carbon steel has been affected more than those containing 0·18% and 0·28% carbon respectively; not only is the embrittlement greater as judged by the impact value but obviously a premature break was obtained in the tensile test. It will be recalled that this low-carbon material contained some ferrite in the softened condition and was shown definitely—by X-ray analysis—to form a small amount of the compound FeCr on prolonged annealing; raising the carbon content to 0·18% probably eliminated

most, if not all, of the ferrite and undoubtedly this constituent would not be present at 0·28% carbon.

Similar tests were carried out on steels containing 20% chromium and 15% manganese, and these gave very interesting results. As shown in Table XI, the lowest carbon steel (0·15%) hardened considerably as a result

TABLE X.
Effect of Carbon Content on the Properties of Steels containing 15% Chromium and 15% Manganese.

Steel.	Treatment	Y.P. Tons/in.²	M.S. Tons/in.²	E.%	R.A. %	Brinell.	Impact Mkg./cm.²
C 0·07 Mn 15·1 Cr 15·0	W.Q. 1,200°	14	47	47	32	196	29·5
	,, 16 hours 700°	26	80	6	—	259	3
C 0·18 Mn 14·8 Cr 14·7	W.Q. 1,200°	17	53	52	52	202	31
	,, 16 hours 700°	16	60	42	38	250	7·5
C 0·28 Mn 14·9 Cr 14·7	W.Q. 1,200°	20	48	55	50	213	23
	,, 16 hours 700°	22	54	28	25	237	7
C 1·07 Mn 15·5 Cr 15·3	W.Q. 1,200°	33	60	21	20	294	8
	,, 16 hours 700°	62	75	2	—	419	1

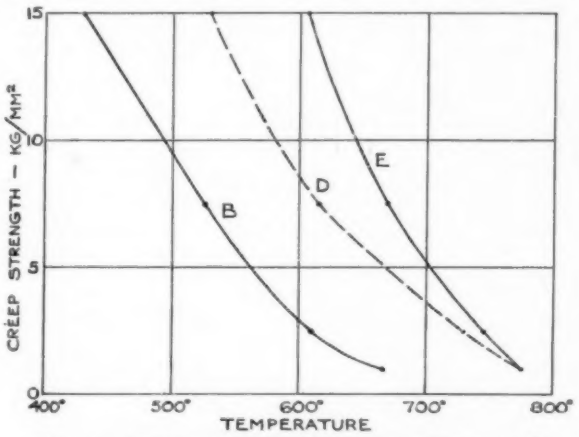


Fig. 8.—Stresses corresponding to a creep rate of 5×10^{-6} per hour. Samples previously W.Q. 1,060/1,100° C. and then annealed at 850° C. for 100 hrs.

Steel.	C.	Si.	Mn.	Cr.	Ni.
B	0·16	0·58	15·7	16·8	1·3
D	0·15	1·59	1·2	25·1	17·2
E	0·18	0·02	16·3	14·2	—

of the formation of the compound FeCr and became so brittle that the tensile test piece broke prematurely with negligible elongation, at a load of less than forty tons per square inch; the impact value also fell to a very low figure. Probably the best results in this series are given

TABLE XI.
Effect of Carbon Content on the Properties of Steels containing 20% Chromium and 15% Manganese.

Steel.	Treatment.	Y.P. Tons/in.²	M.S. Tons/in.²	E%.	R.A. %	Brinell.	Charpy Impact Mkg./cm²
C 0·15 Mn 14·6 Cr 19·9	W.Q. 1,200°	30	42	30	60	211	20
	,, 16 hours 700°	—	38	—	—	395	0·4
C 0·38 Mn 15·4 Cr 20·5	W.Q. 1,200°	30	48	41	50	220	10
	,, 16 hours 700°	41	47	5	6	282	1·5
C 0·50 Mn 14·4 Cr 19·4	W.Q. 1,200°	29	60	58	49	241	15
	,, 16 hours 700°	52	67	6	9	345	2
C 0·82 Mn 15·1 Cr 20·6	W.Q. 1,200°	32	61	25	30	270	7
	,, 16 hours 700°	50	77	5	7	360	1·5
C 1·10 Mn 15·8 Cr 20·2	W.Q. 1,200°	39	65	30	26	301	4
	,, 16 hours 700°	65	78	5	8	392	1

by the steel containing 0·38% carbon and there seems little doubt that even better values would have been obtained from this steel, after annealing, had the initial treatment been at a lower temperature than 1,200° C., e.g., about 1,000° C.; such a temperature would have taken far less carbide into solution and would therefore have reduced the amount separating out as an intergranular membrane during annealing. It is hardly necessary to point out that the carbide remaining out of solution at about 1,000° C. would have "balled up" to a considerable extent.

Resistance to Scaling

Only a meagre amount of data on the resistance to scaling of chromium-manganese steels has been published, but such as there is indicates that their properties in this direction are mainly a function of their chromium content, manganese having no beneficial effect. Fig. 7, for example, summarises results obtained by Schmidt and Legat for steels A, B, D and E, in the Table given earlier, which relate to the losses in weight by scaling of samples heated for 72 hours in a current of air at the temperatures stated. Steels B and E, have good resistance up to 800°C. and A might serve up to about 900° C. at the most (the high silicon content of this steel should be noted). Steel D is, of course, markedly superior, due in part to its higher chromium and silicon contents.

Brühl reports a few tests carried out at 1,000° C., a temperature far too high to give any useful information regarding the behaviour of steels containing 15% chromium or thereabouts. Results on higher chromium materials are reproduced in Table XII and one may conclude that manganese does not improve resistance to scaling in air and that the effect of carbon content is not very definite except in the case of the 30% chromium steels, the results

TABLE XII.
Scaling Tests at 1,000° C. (duration 165 hours).

Composition.				Loss in Grams per Sq. Metre, per Hour.
C.	Mn.	Cr.	Ni.	
0·15	14·6	19·9	—	4·6
1·1	15·8	20·2	—	5·3
0·15	10·4	19·7	—	7·1
1·09	10·9	19·4	—	9·3
0·07	5·4	19·6	—	4·7
1·02	5·5	20·3	—	6·8
0·3	0·7	19·6	14·0	2·0
0·1	15·6	30·1	—	3·7
0·94	15·8	31·1	—	8·7
0·3	0·6	32·3	—	1·1

from which, incidentally, are very poor. Brühl, however, quotes further results, obtained by Hengstenberg, on steels of this chromium content and these, as shown in Table XIII, suggest that the effect of carbon is negligible. A comparison test on a chromium-nickel steel shows the superiority of the latter.

Schmidt and Legat also carried out a few tests regarding creep strength, the steels selected being B, D and E. The results are given in Fig. 8 and give the stresses corresponding to the rather fast rate of creep of 5×10^{-6} per hour. These authors attribute the relatively low creep strength of steel B to the fact that it had a duplex structure of ferrite and austenite, steel E being presumably completely austenitic, but it seems questionable whether this is a complete explanation. Moreover, as the results given for the chromium-nickel steel D are considerably lower than have been quoted previously in other German publications as applying to material of similar composition, the apparent superiority of the chromium-manganese steel E needs further proof.

It may be concluded from this survey of the available data regarding chromium-manganese steels that the latter have only a limited range of usefulness as heat-resisting steels. Owing to the maximum content of chromium having to be restricted to prevent the formation of any appreciable amount of the compound FeCr, the steels which seem to be most suitable for practical use possess adequate resistance to scaling in air up to a temperature of not more than about 800° C. with a possible extension to 900° C. by the use of the rather less satisfactory alloys containing 18 to 20% chromium and 8 or 9% manganese.

One of the advantages of the chromium-manganese, as compared with chromium-nickel, steels is their better resistance to the attack of sulphurous gases, and from

this point of view alone, they are worth further investigation. One direction which this may take is in relation to the

TABLE XIII.

Scaling Tests on 30% Chromium Steels, duration 200 hours (Heugstenberg).

Composition.					Loss in Weight (grms. per sq. metre per hour) at	
C.	Si.	Mn.	Cr.	Ni.	1,100° C.	1,200° C.
0·12	0·18	11·6	29·7	—	2·80	5·55
0·59	0·36	12·1	30·2	—	3·65	6·85
1·14	0·58	12·3	30·7	—	2·81	6·26
0·15	1·50	0·5	25·0	20·5	—	1·56

properties of austenitic steels containing 0·2 to 0·3% carbon. Brühl's investigation showed that these steels hardened and lost much of their toughness on prolonged annealing. As mentioned earlier, however, his initial treatment at 1,200° C. undoubtedly increased these effects and it is at least probable that more satisfactory behaviour would have been noted had the softening treatment been at a lower temperature—e.g., 1,000° C. or so—which did not take so much carbide into solution. Chromium-nickel-tungsten heat-resisting steels containing about 0·3% carbon are regularly used in practice with good results; they are not generally softened at 1,200° C. however, and if they were, it is likely that their mechanical properties would suffer.

Another possibility of increasing the temperature range in which chromium-manganese steels possess adequate resistance to scaling lies in the addition of suitable amounts of silicon. It is well-known, of course, that silicon acts structurally in a similar fashion to chromium and hence, in order to retain a preponderatingly austenitic structure, an addition of the former element would probably need to be balanced by a reduction in chromium content. Experience with chromium-silicon valve steels, however, has shown that a suitable addition of silicon to a chromium steel increases enormously the resistance of the latter to scaling. There is a possibility, therefore, that a suitable balance of chromium and silicon contents would produce an enhanced resistance to scaling combined with a favourable microstructure. In fact, in the discussion of the papers by Brühl and by Schmidt and Legat at Düsseldorf, claims were made by one speaker, G. Riedrich, of Krefeld, that such steels can be produced and that they may possess adequate resistance to scaling at temperatures even as high as 1,100° C. No details were given regarding this claim, but the subject is one which is well worth investigation.

Wetting of Metals by Molten Metals

WETTING is a chemical phenomenon akin to adsorption and although it has been closely studied in the case of liquids in contact with liquids, there is not much accurate information on the wetting of metal surfaces and on the surface forces involved. The attractive forces at the surface of solid metal must be large enough to overcome those within the molten tin or solder. Wetting occurs most readily when the metals concerned form compounds easily; for example, tin, in quite small amounts, enables lead or bismuth to wet copper. A review of present knowledge on this subject, with particular reference to tinning and soldering, has been made by E. J. Daniels and D. J. Macnaughtan.

Fluxes are complex in their action. Further work may explain why, if fluxes lower the surface tension of the molten metal, so that it can spread more readily on the solid metals, they do not hinder penetration into capillary spaces such as the joints in can bodies. There is a critical temperature above which each metal spreads rapidly, and in some cases there is a period of induction before wetting occurs. Reference is made to the halo effect observed in the spreading of certain molten metals.

Copies of this publication may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C. 2.

Interchange of Technical Publications

THE fourth annual meeting of the members of the Organisation for the Interchange of Technical Books and Periodicals was held at the Sheffield City Library, on December 6, 1937, Dr. R. J. Sarjant presiding. In some respects, the organisation is quite unique, and a review of its origin and purpose will not be without interest. Primarily, it aims to make known, and to obtain, the greatest possible use of the technical books and periodicals in the many important specialist libraries in Sheffield.

The advantages of such an association were suggested in a paper read at the Ninth Conference of the Association of Special Libraries and Information Bureaux, by Mr. J. P. Lamb, City Librarian, Sheffield. In December, 1932, the Sheffield City Libraries' Committee invited the University and a number of Sheffield societies and firms to send representatives to attend a preliminary meeting to discuss the question of pooling their resources in technical literature. Dr. R. S. Hutton, who was present as the representative of ASLIB, stressed the benefits of such co-operation, and the cordial way in which the meeting received the idea gave encouragement for the ultimate success of the venture. Eventually, 15 bodies agreed to associate—a number that has since risen to 22. A committee was elected to formulate rules and practical methods for the working of the scheme with the City Library as the administrative centre.

Union catalogues of the periodicals, and the books in the libraries of the members have been compiled. Actually, excluding complete duplicates, there are 1,085 files entered in the list of periodicals. Copies of the list have been prepared and supplied to members, but the location of the files is not shown. This must be ascertained from the City Library, which thus has a means of controlling the scheme. Sufficient space has been left for alterations and additions to be made, particulars of which are regularly circulated.

The development and effectiveness of the organisation is revealed in the number of items interchanged between members. The issues recorded for twelve months in 1934 and 1937, respectively, were 291 and 707. A most important point is that since the inauguration of the organisation in February, 1933, 318 books and periodicals have been obtained locally with the minimum of delay, which otherwise could have only been obtained, if at all, through the Regional Lending Bureaux, or the National Central Library, with consequent loss of time.

The potentialities inherent in the schemes are shown in the recent adoption of a co-operative method for dealing with translations. A member intending to have a translation made of a technical article may ascertain through the City Library if any other members would care to join and share the cost. Three translations have been made in this manner, one from the Russian, and two lengthy German articles. Under the rules of the scheme members will also lend translations in their possession.

In some ways Sheffield is an ideal centre for interloan. It is mainly concerned with one industry—the manufacture and working of ferrous metals. In addition to the University, it is the seat of the Society of Glass Technology, and the Safety in Mines Research Board, whose invaluable libraries have been found indispensable to the organisation. The great steel works, English Steel Corporation Ltd., Thomas Firth and John Brown Ltd., Hadfields Ltd., United Steel Companies Ltd., to name only some of the largest of them—possess highly important specialist libraries upon which the organisation may draw.

Moreover, through the contacts now established, the staff of the Science and Technology Department of the City Library has ready access to the advice of expert staffs and research workers in the selection and co-ordination of book stocks, and in dealing with difficult technical reference queries.

Progress in the Nickel Industry

The service properties of the various alloys with which nickel is associated are such that nickel has been used to an increasing extent during the past year. The uses of this metal are so varied that only brief reference is made in this article to the more important.

IT has been said that advances in the knowledge of metals have been greater during the last ten years than in any preceding period since the Bronze Age. There is undoubtedly much truth in the statement and the growing application of a wide range of metals, formerly regarded as of minor importance, is an indication that engineers are more metal-minded to-day in their desire for materials which give satisfactory service under increasingly severe conditions. Among the many advances made, the application of nickel is probably the most outstanding. Although nickel is one of the most ancient of metals known to man, it is only during comparatively recent years that this metal has risen from minor to major importance.

Nickel was known to the Chinese, though not under its present name. At least, as long ago as the Han Dynasty they manufactured an alloy from copper-nickel ore called pei-tung (white copper). The Bactrians, an ancient Asiatic race, who inhabited the land north of the Hindu Kush range of mountains, now known as Russian Turkestan, were also familiar with nickel. It is probable, however, that the Bactrians gained their knowledge of the metal from the Chinese more than 2,000 years ago. There is no evidence that any progress was made in separating the metal until the eighteenth century. During the early part of that century Swedish and German miners were much troubled by an arsenious ore, owing to its deceptive resemblance to native copper. They termed it *kopparnickel* or *kupper-nickel*, "devil's worthless copper," from a form of the German *nicklaus*, which is represented in English by "Old Nick." Cronstedt examined the ore and in 1754 isolated the metal it contained and, reasonably enough, he called the metal nickel.

Nickel is rarely found native; its ores are complex mixtures, divisible into three classes: sulphides, silicate and arseniferous. The most important mines are those of Sudbury, Ontario (sulphides), and of New Caledonia (silicate). Mines in different parts of Europe produce smaller quantities of arseniferous ores. The largest deposit known is that in the district of Sudbury and a brief reference to its discovery will be of interest. In 1883 a construction gang were at work near Sudbury making arrangements for the laying of the Canadian Pacific Railway, across the little-known upper Ontario, when it was noted that part of the earth was of a reddish colour. This led to the discovery of copper ores. Prospectors soon staked out claims, mining started on a considerable scale and the first ore was soon on its way to smelters. There the ore was put through familiar processes, but for some reason could not be worked properly. Investigation showed that the cause of the trouble, as in the case of the early Saxon ores, was nickel. But this troublesome nickel has proved to be more valuable than the copper.

The great problem had been to separate nickel from the other elements in the ores, and the discovery which led to the surmounting of this obstacle and the rapid advance in the production of nickel, is a romance both of science and industry. The discovery was made by Drs. Mond and Lange, whose attention was called to the accidental corroding of a nickel valve. The valve was coated with carbon, which led to a study of the effect of carbon monoxide on nickel. It was found that at a temperature of about 50° C. nickel forms a volatile compound with carbon monoxide, known as nickel carbonyl, which easily decomposes again into pure nickel and carbon monoxide by raising the temperature to about 150° C. From this it was deduced that nickel could be isolated in the pure state by treatment with carbon monoxide, which has no effect on other metals in nickel bearing ores. This method, known as the Mond process, simplified production and led to the present progress and prosperity in the nickel industry.

From the days of the early Chinese, when nickel was usually associated with copper, right up to modern times, nickel was of minor importance. Up to 1875 the world's total output was about 500 tons a year; with the development of Sudbury and New Caledonian ores, and progress in the application of the metal, production advanced to 11,810 tons in 1904, in 1929 production was in the neighbourhood of 60,000 tons, while in the year just closed, the world consumption of the metal has exceeded 100,000 tons.

The great increase in the consumption of nickel during 1937, about 24% greater than in 1936, is due to the improvement in world industry, the larger output of products containing nickel as an established component, the introduction of nickel into new products and the spread of nickel consumption in new industrial countries. Another significant factor has been the rapid development of mass production by manufacturing processes involving highly corrosive conditions, where nickel, high-nickel alloys, Monel metal, stainless steel and various alloy-clad steels provide industry with materials combining requisite strength with the essential resistance to corrosion.

During more recent years, nickel has become a feature of everyday life as a result of the wide diversity of its applications, and practically every industry uses the metal in some form. In the automobile industry, increase in the use of nickel has been stimulated by the greater use of heavy road vehicles, in which ruggedness is an important consideration, especially as they are frequently run by corporations, which insist on high standards of performance. Here the nickel steels and nickel cast irons are being used for an increasing diversity of parts. On the railroads increase in the operating speeds and decrease in deadweight haulage of both passenger and freight equipment were notable trends in the increase of nickel steels and other nickel alloys in this field during 1937. Renewed activity in shipbuilding was associated with a trend towards cupro-nickel condenser tubes for merchant vessels, and it also has been accompanied by a growing interest in nickel alloy steels in various marine installations. The acceptance of nickel steel rivets as approved material for hull construction is a case in point. While much nickel is used in liners and warships, a great potential field for nickel lies in the cargo vessels and, in addition to the wider use of nickel alloy turbine blading and nickel steel shafts, the growing use of nickel-clad steel as lining for the fish holds in trawlers and the increasing popularity of Monel metal for propellers, are developments of equal promise.

In the chemical industry modern methods of mass production depend upon the availability of materials which can provide strength and other physical properties together with resistance to the corrosive substances characteristic of this industry, and nickel in various forms is proving invaluable. Improvements in the metallurgy of malleable nickel and many high-nickel alloys have made these materials suitable for many applications, but nickel is so closely associated with many industries that a brief reference to some of the principal applications will be of interest.

STEEL

The constantly widening field of alloy steels has maintained its position as the largest single consumer of nickel since the early nineties, and last year about 55% of the world's nickel production was used in this way. Within this field, changes occur as established alloys are further improved and new combinations of metals are developed, present interest being directed largely to the extending uses of the stainless steels, the weldable, high-strength constructional steels, heat-treatable steels low in alloy content, permanent-magnet steels and alloy cast steels.

Constructional Steels

These alloy steels, which contain from ½% to 5% of nickel often with additions of chromium, molybdenum, vanadium or copper, comprise the group used largely in the construction of various types of motive power in transportation, as well as in oil field equipment, machine tools and equipment for the heavy industries. Although these steels are relatively low in nickel content, the aggregate tonnage of their use in industry is so high as to constitute the most important factor in nickel consumption. Nickel-molybdenum steels further strengthened their position as materials for the highly stressed parts of vehicles. During the past year a large producer adopted a nickel-molybdenum steel for ring gears on private cars and reports that distortion of the gear in heat-treatment has been reduced, and that more than 300 pieces can now be produced per cutter grind, as compared with about 125 pieces from the material formerly used. An important parts manufacturer now uses nickel alloy steels for all starter gears, and has developed an interesting application of 30% nickel steel in speedometers and voltage control units. This special nickel steel has been selected because of its change in magnetic permeability with change in temperature.

In railway engineering, the trend is definitely towards higher pressures and speeds in steam locomotives, and two of the railways in this country, in shortening the running time between London and Scotland, have utilised nickel steels in order to save weight and increase power. In the case of the featured stream-lined locomotives on one of these lines, which average 62 m.p.h. for the 400 miles between London and Glasgow, nickel steels are employed for boilers, and nickel-chromium-molybdenum steel forgings are used for the connecting and coupling rods. High strength nickel alloy steels have also been adopted for the reciprocating components of the locomotives on the second of these railways in the operation of heavily loaded trains between London and Edinburgh. A third railway has adopted nickel-chromium-molybdenum steels for connecting rods, coupling rods and valve gears for one of its newly designed locomotives having increased boiler capacity.

Just as higher speeds have stimulated the use of nickel steel forgings for connecting rods, so have the higher pressures produced a demand for nickel steel boiler plate. During the first half of 1937 more than 200 locomotive boilers were specified in nickel steels. Progress continues in the use of 1¼% nickel steel rivets for boiler construction.

The nickel alloy steels, of the types covered in various specifications found broader application in the aviation industry for gears, bolts, valves, crankshafts and connecting rods in aeroplane engines, as well as for struts, landing equipment and fittings. They also continue to meet the many and diverse requirements of the oil industry, where the severity of service and the cost and inconvenience of metal failures appear to have relegated price consideration into a secondary position. In pumping wells, nickel steels are employed for sucker rods, pump and engine parts, and parts of the beam equipment. The large tonnage of sucker rods is becoming increasingly dominated by the nickel-molybdenum steels.

The trend of refineries to carry out more varied reactions with petroleum fractions leads to the belief that the applications of nickel alloy steels will be increased further. The large number of corrosion test spools in refineries reflects the need for corrosion resisting materials, and present indications from examination of these spools are that nickel alloys will solve many of the needs for materials, arising from the new refinery technology.

In solvent dewaxing the need is for materials which will retain toughness and impact value at low temperatures (−75 to −100° F.). The wrought and cast steels with from 2% to 3% of nickel possess the required performance qualities and response to the usual methods of fabrication. Among their important applications are in vessels, pumps, bolts, piping, valves and fittings.

Nickel alloy steels maintained their prominence in the machine tool field, where the better steels are required for many applications to reduce maintenance and service costs. Their use also expanded in the manufacture of hand tools. Developments in the mining field have included further progress with 2% nickel steel for mine cage couplings, this material now being standard in the major French and Belgian mines. An outstanding example of modern bridge construction completed during the year is the San Francisco-Oakland Bay Bridge which contains 3,680 tons of 3½% nickel steel in the forms of anchor plates and structural shapes. Use of this steel resulted in lighter sections with a consequent reduction in dead load.

Supplementing the general range of low alloy constructional steels which are quenched and tempered before use, is a group of nickel-copper alloy steels which are finding varied applications where improved strength, as rolled, combined with cold forming and welding properties are demanded, and where the cost of highly corrosion resistant alloys is not justified. Although such steels have been in commercial production for less than three years, they have accounted for a consumption of a substantial tonnage of nickel. They comprise a group of proprietary products and they contain nickel in amounts up to 2%.

Cast Steels

Nickel alloy cast steels were used in significant quantities in their accustomed fields where reliability and improved mechanical properties are desired. Such fields include miscellaneous heavy machinery, ships castings, river control equipment goods and private car parts and mining and excavating machinery. The normalised nickel-manganese steels, containing about ·30% of carbon and 1·4% each of nickel and manganese, which were developed commercially only two years ago, have had a striking record in the railway field.

While it is difficult to determine the tonnage of nickel steel castings going into rolling mill service, because of the diversified uses and sources of supply, this industry is known to be a very large user of these products. Cast-steel rolls are first in importance, and practically all roll makers producing cast steel rolls are already using some nickel. One manufacturer is promoting, under a trade name, blooming mill, breaking down and backing up rolls of a nickel-chromium-molybdenum steel containing more than 1¼% of nickel. A second manufacturer, has increased production of nickel-chromium steel rolls. Another development in rolling mill equipment has been the introduction of an open hearth charging pan of cast nickel-vanadium steel. More than 400 of these castings have been placed in service during the past year. Large pinions and gears for rolling mill service continue to be made of 3½% nickel steel or nickel-chromium-molybdenum steel, where high fatigue and impact stresses are encountered.

Piercing points of nickel-chromium-molybdenum steel have retained an important place in the production of seamless tubing. The composition used contains approximately 3% of nickel along with other alloys. Besides possessing hot strength and high toughness at high hardness, these points acquire, in service, a tightly adhering scale which is necessary to permit the point to function properly,

a characteristic largely provided by the nickel in the steel.

Cast-steel die blocks are being made of nickel-chromium-molybdenum steels, with or without additions of vanadium, in cases where the machine work on such dies can be reduced appreciably by moulding-in the impressions. Drawing dies cast from a special nickel-chromium alloy have proved unusually successful in stamping sheet metal, a die of this type having produced 176,000 tubs for washing machines without need of redressing the die.

Mine car wheels and couplers, grizzly rolls, sheaves, gears and hoisting drums are among the applications of nickel steel castings in the mining industry, and nickel-chromium steel containing 3% of nickel is used for mill liners and rollers in the manufacture of cement. Increased production of power shovels, locomotive cranes, tractors and road machinery, as well as of parts for replacements, afforded a larger market in this field for cast nickel alloy steels. Several large shovels for strip coal mining were completed during the year. In this type of heavy machinery nickel-chromium and nickel-chromium-molybdenum steels are used for dipper teeth, lips and points, and for sheaves, gears, tractor shoes, sprockets and rollers; nickel-manganese steels, quenched and tempered, are used for crawler pads, grouters and sprockets; and, in the normalised condition, these and nickel vanadium steels are used for frames, gears and pinions. An appreciable tonnage of cast nickel steels is also consumed in the oil industry. Nickel molybdenum steel is popular for brake drums, fishtail bits, bit bodies, and reamer bodies, as this composition is readily weldable in the medium carbon ranges.

Stainless Steel

There are many different compositions of stainless steel in commercial use. The most widely-known type, which contains 18% of chromium and 8% of nickel, has shown spectacular commercial development. Removal of the carbide difficulties through the addition of titanium or columbium is a noteworthy step forward, whilst the use of the molybdenum-bearing material has been highly successful where corrosive conditions are unusually severe. One of the largest producers of this type of alloyed steel, reports that miscellaneous sales are growing more rapidly than any other division, more than one-third of the company's stainless steel business being included in this general classification.

The success of the stainless steel streamlined trains built by welding method in U.S.A. has led to other uses of stainless steel in railroad equipment. Examples include the streamlined sheathing of steam locomotives, the construction of separate passenger cars which are interchangeable with the standard weight cars, and the building of mono railcars. The stainless steel railcar recently developed by one of the leading French builders of railroad equipment has attracted considerable attention both at the International Railway Congress Exhibition and at the Paris International Exposition. Forty such cars are being built for the Chemins de Fer de l'Etat and will be put into service early in 1938.

Use of stainless steel for exhaust manifolds and accessories is now well established among French manufacturers who were the pioneers in using this alloy for fuselages; and in Germany, tube welded assemblies of stainless steel are being experimented with for both aircraft and hangar construction. The "18/8" type of stainless steel is widely used in oil refining to protect reaction vessels operating at elevated temperatures in the presence of sulphur. This material has been found especially useful in connection with solvents of the phenol group, and is used as tubes in heating coils and evaporators; also as the liner for vessels and pipes. Other applications are as valve trim, pump impellers, thermo-couple wells and gauge parts and trim. Higher turbine velocities have introduced the necessity for stronger blades which are now being made of stainless steel. A producer in the U.S.A, has developed for high temperature turbine blading a special high chromium-nickel steel with additions of titanium and aluminium.

The food and beverage industries maintained their position as a steadily increasing market for stainless steel equipment and utensils. Use of this alloy in restaurants for cooking and for serving dishes has gained extensively. For tanks and tubes it is in increasing demand in breweries, where new applications include a special type of waggon for handling yeast, and steam coils for heating vacuum pans.

Indicative of the growing use of stainless steel for architectural and decorative purposes is the statue of this material, which dominates the Russian exhibit at the Paris International Exposition. Her Majesty Queen Mary has selected stainless steel for the service equipment in the kitchen of Marlborough House, her new home, where the same material is used for locks and door fittings. Numerous additional applications could be cited to show how this material is appreciated in widely differing conditions.

CAST IRON

World consumption of nickel in cast iron increased 30% during the first ten months of 1937, thereby establishing a new high mark. Production figures indicate that 60% to 70% of the total alloyed cast iron tonnage of Canada and the United States contained nickel, thus showing a substantial margin in favour of nickel as an alloying element. One third of the iron foundries in the United States are now producing alloyed cast irons, many foundries turning out as much as 30% of their output in this form. The average increase of nickel consumption in alloyed cast irons was particularly noticeable in connection with the greater activities of the mining, textile, petroleum and paper industries.

The automobile industry in particular increased its use of nickel alloyed cast iron for cylinders, clutch plates, brake drums, exhaust manifolds and similar parts. Growing acceptance for cast-iron camshafts resulted in further progress in alloyed irons in the automobile field. Its use in Diesel engine production also increased markedly in 1937. Construction of such engines is now subject to the same general specifications as have been established for automobile engines, including in addition the frames which in some cases are produced in nickel alloyed cast irons. The severe duties to which Diesel engines are being subjected gave marked impetus to the use of nickel alloyed irons. It is interesting to note that the smallest Diesel engine now being built in the United States, is a 3 h.p. vertical, single-cylinder machine whose engine frame is a single piece of nickel alloyed cast iron; whilst cylinder, piston and piston head are of the same material. The machine tool industry has enjoyed one of the greatest years in its history with an accompanying increased use of nickel cast irons. One of the oldest industries, which has been a consistent user of nickel-alloyed castings—coal and coke—continued to increase its use of Ni-Hard castings. Prominent among the applications in this field, adopted primarily for their quality of resisting abrasion and corrosion are crusher rolls, disc pulverisers, ball mill pulverisers, ball mill liners, wearing plates, ash conveyor pipes, ash sluices and sand and sludge pumps.

During the year, an outstanding event in cast iron production was the cupola processing of light and heavy castings for the chemical industry, in which 30% of nickel and 3 to 4% of chromium constituted the essential alloying elements. The production of this alloy in ordinary foundry equipment is leading to an increased demand on the basis of its resistance to corrosion and to staining and other contaminating effects.

Among other divisions of the chemical industries, which required larger quantities of alloyed cast irons of the Ni-Resist type, were those producing caustics, soap and salt. These alloys are used for many equipment parts, such as pumps, filters, pipe, soap rolls and a variety of conveying, processing and packaging machinery.

In oil refineries, Ni-Resist increased in popularity, and its use has been widely extended. Its application is general in the body and impeller of centrifugal pumps handling water, oils and acid sludges; also as the liner, piston and rings of reciprocating pumps handling the same materials. Valves controlling acid sludge services in refineries and handling acid treated stocks of various kinds are made of Ni-Resist alloyed cast iron to minimise corrosion. Headers of the same material have recently been put into use with coolers handling petrol treated with zinc chloride.

SPECIAL PRODUCTS OF THE NICKEL INDUSTRY

Besides the various nickel-bearing alloys produced by rolling mills and foundries, the customers of the nickel industry, the latter is itself the direct producer of malleable nickel and of several non-ferrous alloys with high nickel content. They are commercially used because of their combination of corrosion and heat resistance with high physical properties. These are the alloys of the monel series, the copper-nickel series, and inconel, which are available also in the "clad" forms permanently bonded to steel. Also included are the nickel chromium and nickel chromium iron alloys.

The trend towards more exacting specifications for materials in processing equipment not only increased the market for these alloys in the fields in which they were already established, but also extended their use in industries in which nickel had previously had only an experimental status. As a result the year has shown an increase in the consumption of malleable nickel, Monel and other high nickel alloys.

Monel metal maintained its long established position as a leading material for engineering and chemical application in the various industrial fields. In the newer fields of household applications increasing tonnages are being realised for hot water storage tanks, cabinets, stoves and kitchen equipment. Progress has been made with foundries in standardising casting procedure, and an improved type of ingot, which is completely "killed" and gas free, is now being supplied to them. The variety of service conditions under which Monel metal is employed for its corrosion resistance in oil refineries, is indicated by its wide use at sub-zero temperatures, by its presence in equipment exposed to sulphuric acid solutions at temperatures up to 225° F., and by its use as a protective liner for pipes and the shells of condensers exposed to the action of hydrochloric acid from chlorinated solvents or from cracked salts. Injection valve stems, orifices, meter parts and valve trims of Monel metal are now widely used on pipe lines handling both liquid fuel products and natural gas. Cables and lines of monel find application in gauging equipment and also in controlling certain types of swing pipes.

Expansion in home building and home modernisation, continuing in 1937, carried with it the demand for the well established products of nickel and the nickel alloys as well as for the many new applications of these white metals. Monel metal further strengthened its position as a metal for the modern kitchen, leading manufacturers having adopted it as a quality material throughout their kitchen equipment. The vigorous competition between the gas and electrical industries for household service has been, in fact, a stimulus to the extended use of this alloy.

An important factor in increasing nickel consumption in the chemical and other fields has been the development of a process by which pure nickel can be permanently bonded to steel in order to provide a material with high strength and corrosion resistance at comparatively low cost. Wherever highly corrosive substances are handled in bulk, these clad materials are being called upon more and more in the construction of equipment for transporting, storing and processing the chemicals. Examples of such applications include the manufacture of synthetic resins from phenol, the sulphonation of oils, the bleaching of textiles with alkaline solutions of hydrogen peroxide, the production of caustic soda and the making of soaps.

Another type of application is in the protection of foods, beverages and pharmaceuticals from contamination and spoilage, a notable example being the continuing use of nickel-clad steel to line the holds of trawlers bringing fresh fish to market from offshore fishing banks.

ELECTRICAL RESISTANCE ALLOYS

Expansion in the use of electricity both for industrial heating and for household heating and cooking appliances throughout the world has led to substantial increase in the use of nickel for the production of electrical resistance wires and elements. Much was accomplished during the year through technical research to provide material of longer life. As a result new avenues have been opened, particularly in the field of industrial applications where the advantages of unadulterated furnace atmospheres are of great economic importance.

HEAT RESISTANT ALLOYS

The year was notable for advance in the continuous process for carburising steel, using gas as the carburising medium and nickel-chromium iron alloys containing 35% of nickel for the muffles. This method effects considerable saving over the cost of box carburising. Increased use of salt baths as a heating medium in the annealing and heat treating of metals and alloys has resulted in a greater demand for chromium nickel iron alloy pots and electrodes as well as for pure nickel electrodes. Radiant tubes of chromium-nickel iron have replaced internally fired refractive type tubes in bright annealing and non-ferrous metal melting. Vertical gas fired tubes have also come into extensive industrial use in radiant gas fired furnaces for enamelling, normalising and annealing steel products.

The enlarged demand for nickel alloys of the heat resisting type results from the increased mechanisation of heat treating furnaces. 70% of the continuous normalising furnaces used in steel mills are now of the roll conveyer type. This use of rolls has advanced markedly because of the recent developments in production of centrifugal castings and the electrical resistance butt welding of these alloys. With the increased use of continuous brazing operations, alloys with substantial nickel content have been developed to withstand the high temperatures and protective atmospheres involved in the process.

NICKEL PLATING

Nickel plating has risen rapidly in favour as a protective coating for metals in a growing number of industrial and commercial applications. The year saw an accelerating demand for nickel in world markets with emphasis laid on its corrosion and tarnish resisting qualities rather than on its decorative effect. The electrolytic deposition of nickel now accounts for approximately 10% of the year's output, and preliminary estimates from the United Kingdom, Canada and in the United States indicate that world consumption of nickel for this purpose increased by 30% during the first ten months of 1937 over the corresponding period in 1936.

Significant technical advances have been made in the new process of bright plating. This process is drawing out of its test period and has been more generally adopted for large scale work, both in the United Kingdom and in the United States. It effects overall savings in plating and finishing costs of 10% and more, because it practically eliminates the need for buffing after plating. Savings are proportionately greater, the heavier the coat.

Special applications of nickel plating have multiplied during the year and two new products have been put into production, which may have far-reaching effects. A manufacturer of cold rolled and plated strip steel developed

a continuous process of plating, annealing and cold rolling, which results in a finished strip of attractive appearance and high ductility.

NICKEL SILVER AND COPPER-NICKEL ALLOYS

Nickel silver is one of the older forms of metal alloys, which is finding increasing markets, not only as a decorative material, but also for its good corrosion and tarnish resisting qualities. While its more spectacular use is in architectural decoration, it is no less important in the manufacture of food handling equipment and as the base for silver plated tableware. Other applications are springs and electrical resistance wire.

The rate at which large manufacturers took up the casting of nickel silver during the year, indicates a ten-fold increase in its use in the food handling equipment field alone. These castings are going into ice cream freezers, milk and pasturising apparatus, fruit juice extractors, valves used in the dairy industry, bottling machinery and carbonators, as well as for architectural purposes.

Replacement of older materials employed in the manufacture of condenser and heat exchanger tubing by cupro-nickel continues at an increasing rate, particularly in marine power units and in oil refining equipment. The superior resistance of cupro-nickel to salt water corrosion as compared with the more common brass and bronze materials has led to its wide use for such purposes.

NICKEL BRASS AND BRONZE CASTINGS

Educational work over the past three years was reflected in an increased demand for nickel alloyed with bronze, where it is of particular importance in producing pressure tight castings. The use of nickel in high duty bronzes and brasses is being increasingly appreciated.

MAGNETIC ALLOYS

Marked interest was shown during the year in the relatively new nickel-aluminium-cobalt magnet steels as permanent magnets, which bid fair to invade the field heretofore occupied by electro magnets. Their permanency under conditions of vibration and heat holds promise of growing applications. In the neighbourhood of 300,000 pounds of such steels are the estimated production for the year.

Permanent-magnet materials of this character are being produced in increasing quantities for leading manufacturers of radio equipment and of small motors, relays, magnetic chucks, hand magnets, precision instruments, magnetic blow-outs, lifting devices, generators and circuit breakers. A novel use is for percolator tops that do not fall off.

Non-ferrous Metals and Alloys for Corrosion Resistance

CONSIDERABLE attention, during recent years, has been given to corrosion and corrosion resistance by non-ferrous metals and alloys. Much research work has been carried out with a view to the improvement of knowledge on the subject, and also to supply the engineer with serviceable material to suit the varying conditions of industry. The results of many investigations have been published in various papers and a correlated abstract of a number of them by V. V. Kendall* is of considerable interest. They deal with nickel, aluminium, copper and their alloys, and with lead, silver and zinc. Corrosion media are classified under ten headings, comprising air, soil, acids, oxidising agents, natural waters, salts and brines, foods and organic materials, high temperatures, alkalis and sulphur compounds.

It has been established that six of the ten classifications (air, soil, acids, oxidising agents, natural waters, salts and brines, foods and organic materials, and alkalis) are well resisted by nickel whilst a reasonable degree of resistance is offered to three of the other classifications. In the presence of high temperatures, nickel has the quality of forming a protective scale when oxygen is present, and only sulphur compounds make it readily acted upon.

The nickel-copper alloy known as Monel metal appears to possess useful resistance to a greater number of corrosive media than any other metal. The most recent development in Monel alloy is the addition of 3·5% aluminium to produce K-Monel, and the addition of 2·75% and 3·75% Si to produce H-Monel and S-Monel, these two being available only in cast form.

Inconel, of 79% Ni, 13% Cr, and 7% Fe, was first developed for resistance to corrosion and tarnishing by foodstuffs, especially fruit juices and dairy produce, and it has the further advantage that it is resistant to a considerable variety of other corrosives, being practically free from attack in strongly-oxidising acid solutions.

The Hastelloys of 58% Ni, 20% Fe, 20% Mo and 2% Mn ; 58% Ni, 6% Fe, 14% Cr, 17% Mo, and 5% W ; and of 85% Ni, 3% Cu, 2% Al and 10% Si, have been proven strongly resistant to acids and to corrosive chemicals. Illium is superior for application under highly oxidising conditions such as nitric acid, and has limited applications for use in contact with hydrochloric acid and acid chlorides. This is only available in cast form and has the composition : 56% Ni, 8% Cu, 24% Cr, 4% Mo, 1% Si, 1·5% Mn and 2% W.

Aluminium and its alloys owe much of their corrosion-resistant properties to their film formation characteristics. The Cu-Mn-Mg alloys are widely used jor aircraft work and, by the addition of a small amount of chromium forging properties are improved ; the common wrought alloys containing varying amounts of manganese, magnesium and chromium.

Copper, brasses, bronzes and copper-nickel alloys have also been the subject of considerable thought and development. The copper-beryllium alloys are of strong interest ; for instance, beryllium copper (2·0—2·25% Be) produces a ductile structure when quenched from about 800° C. and is capable of cold working by ordinary commercial procedures ; also, it can be hot-worked between 575° C. and 775° C., whilst reheating after forming will harden and strengthen the alloy, it then becoming suitable for springs and for articles requiring high corrosion resistance, high resilience and high fatigue resistance.

The addition of tin corrects the tendency of aluminium brasses to dezincification. The precipitation-hardening types of nickel aluminium bronzes found many applications. Both the available types possess great strength and sound corrosion resistance.

Possibly the most important development in regard to the use of lead is that of Tellurium lead (0·05% Te), this having exceptional resistance to hot concentrated sulphuric acid, with a higher fatigue limit than pure lead, and can be work hardened. Although higher tensile strength is obtained by the addition of tin, antimony and cadmium to lead, the effect on corrosion resistance qualities needs further study. Calcium additions have been used successfully in lead, for bearing alloys and for telephone cable sheathing. In the production of high-purity commercial zinc the addition of 1% silver to lead forms an insoluble anode particularly useful in plating work.

Zinc sheet is now being used for corrugated roofing sheets, having additions of small quantities of cadmium, copper and magnesium ; and a new type of electro-deposited high-purity zinc is applied to steel wire before mechanical treatment is given to the coated wire, and it is anticipated that this zinc-coated steel wire will prove more serviceable than ordinary galvanized steel or iron wire.

Silver is used for considerable chemical equipment ; in the food, photographic and rayon-acetate industries, for example. The production of phenol entails the use of large quantities of silver.

* *Metals and Alloys*, Dec. 1937, pp. 355-360.

Gases for Controlled Atmospheres

THE difficulties in applying controlled atmospheres to bright hardening offers a promising field of research for the study of the behaviour of typical commercial protective atmospheres on higher carbon steels at high temperatures, and also the exploration of the possibilities of adjusting the gas composition to avoid the fatal decarburisation so often encountered in this field. Experimental work on these problems has been undertaken by the Battelle Memorial Institute and the latest results obtained are dealt with by E. E. Slowter and B. W. Gonser.*

The investigations were carried out on plain carbon steels, as it was recognised that alloy steels would behave quite differently, and that high-speed steel would be a special problem. A series of ten steels were studied, having carbon contents ranging from 0·07 to 1·04%, and several steels having varying carbon contents were treated in the furnace at the same time. The lower carbon steels, normally less decarburised than the higher carbon steels, were placed at the end of the furnace at which the gas entered, except in certain special cases. The furnace used for heating the specimens consisted of a $1\frac{3}{4}$ in. dense porcelain tube, externally heated by an electric resistance furnace, and controlled by means of a thermocouple and an automatic recorder.

Gases used were largely synthetic, prepared from pure components and mixed in the ratio desired. Cylinder hydrogen and nitrogen were purified by passing over copper heated to 750° C. and then dried by calcium chloride and phosphorus pentoxide. In some cases hydrogen was made from zinc and hydrochloric acid, and purified by passing over soda lime, calcium chloride, and phosphorus pentoxide, and in other cases cracked ammonia gas was used. Cylinder carbon dioxide was merely dried over calcium chloride and phosphorus pentoxide before use, while natural gas was used as a source for methane and was purified by passing over phosphorus and the regular drying agents. Carbon monoxide was made from formic and sulphuric acids, passed through alkaline pyrogallic acid and over phosphorus, dried with calcium chloride and phosphorus pentoxide, and finally passed over electrode carbon at 1,100° C. When water vapour was desired in a gas mixture, the incoming gas was passed through a water bottle held at a definite temperature corresponding to the amount of vapour desired. The flow of gases to the furnace was controlled by accurately calibrated flow meters, and the desired mixture introduced into the furnace at a constant rate of 150 c.c. to 160 c.c. per min.

The steel specimens were cleaned with emery paper, washed in alcohol, dried and weighed before being inserted into the cold furnace tube. After flushing the tube with gas to be used until no free oxygen could be detected in the exit gas, the furnace was heated to the desired temperature, held there for a desired time interval, and then cooled with the same flow of gas maintained. The three temperatures at which the experiments were carried out were 750°, 850°, and 950° C., and the time intervals varied from 15 mins. to 3 hours. As a quantitative measurement of the effect of the various gases on the steels, the degree of carburisation and decarburisation was reported in terms of gains or losses in weight per unit of surface area. These were plotted above and below a zero line; points above the line indicating a gain in weight due to carburisation, and points below showing decarburisation. This held true, since there was no scaling in any of the tests and metallographic examinations made from time to time verified the assumption. The weight changes were found to be more sensitive than the microscope, as a weight gain or loss of 0·0001 grm. per sq. cm. was necessary for carburisation or decarburisation to be evident by microscopic examination, even on the low carbon steels. For all practical purposes, therefore, weight changes of 0·0001 grm. per sq. cm. were considered as an absence of any appreciable effect of the gas on the steel.

The primary conclusion derived from these experiments was that for the bright hardening of medium and high carbon steels, without producing scale or decarburisation, both carbon dioxide and water vapour must be avoided, and this can be done by making a gas that does not contain them originally or by removing them by suitable purifications. Carbon monoxide-nitrogen mixtures from which those gases are excluded are suitable for a wide range of carbon steels, and presumably for many alloy steels, excepting those high in chromium. Of particular importance as a gas for practically all steels is nitrogen, or similar inert gas containing only a small percentage of carbon monoxide, which is added to prevent oxidation from infiltered air or gases carried by the work. Carbon monoxide is relatively inactive to carbon steels, and its slight action is reduced by dilution with nitrogen, but, if more than a trace of infiltered air must be combated, more than 5 to 10% of carbon monoxide may be necessary to prevent straining. A very slight addition of methane may be used to overcome any tendency towards decarburisation.

Moisture-free hydrogen-nitrogen gas mixtures, with or without carbon monoxide, but free from carbon dioxide, may be used in bright hardening. While hydrogen has a decarburising effect, this can be counterbalanced, and the gas made neutral by addition of methane, or other hydrocarbon, and this addition may be regulated to fit the carbon content of the steel. As with carbon monoxide, dilute hydrogen, such as 5 or 10% hydrogen-nitrogen mixture, is far less active than a gas high in hydrogen, and is much to be preferred.

The oxygen in carbon dioxide and in water vapour tends to be reactive with iron, while that in carbon monoxide is relatively inactive. The adjustment of a controlled atmosphere by the addition of methane to render it inactive is least difficult when it contains (besides nitrogen) only carbon monoxide, and more difficult with hydrogen. Adjustment is possible with both carbon monoxide and hydrogen present, but is very difficult and in many cases impossible when moisture or carbon dioxide, or both are present.

Definitely carburising gases, such as cracked fuel gas or cracked oil used in gas carburising, are suitable for some classes of work, where some surface carburisation may be permitted. Commercial gases which contain an appreciable amount of carbon dioxide are also permissible for use on low carbon steels, but are not satisfactory for bright hardening of medium and high carbon steels. These gases are not readily adjusted by addition of methane, or by decreasing the rates of air to gas in partial combustion in order to leave unburned methane. Either hydrogen or methane will react with carbon dioxide in the furnace to produce water vapour, with all its accelerating effect upon decarburisation and its tendency to discolour the work. Commercial atmospheres containing some carbon dioxide or moisture may be made usable for bright hardening by adjustment with methane, when short time intervals and comparatively low temperatures are involved, but the reactivity of such gases may still make their use inapplicable because of attack upon resistors and furnace parts.

While the cheapness of protective atmospheres derived from fuel gases is in their favour, when the conditions of treatment are such that elaborate chemical purification is unnecessary, for good bright hardening considerable expensive purification is indicated as being necessary. What may appear to be a costly gas may in the end prove more practical than a cheaply produced partly burned fuel gas, after considering the purification equipment necessary, the effect on furnace parts, on electric resistors, and the sensitivity of the gas to a change in the character of the work.

Metals and Alloys, 1937. Vol. 8, No. 6 and 7. Pp. 148-168 and 184-205.

Turning Locomotive Tyres

By L. Sanderson

Machine turning of locomotive tyres that have been in service is now possible as a result of the development of super high-speed steels capable of turning the hardest and most difficult of materials, and in this article the author gives some essential points to observe in the choice of tools for this purpose.

UNQUESTIONABLY, the turning of locomotive tyres, hardened on the tread by the friction of brakes is one of the most arduous of all the tasks which the machinist in railway workshops has to encounter. Furthermore, it constitutes as severe a test of tool steel quality as can well be imagined. Tyres worn on the tread are invariably more difficult to machine than new tyres, for the reason that the tread is both glazed and hardened by the action of the brake-blocks, and by the wear it receives. Because of these difficulties, certain shops still adopt the practice of removing the tyres completely, putting fresh tyres on the wheels, and running the wagons without more ado and without turning. The rolled skin is not worn to the same extent as the turned tyre, and if the tyres are genuinely circular, and paired within $\frac{1}{16}$ in. diameter, it is possible to obtain the desired running results.

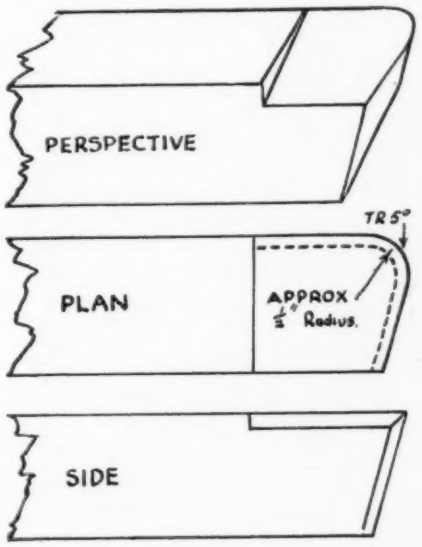
The development of super high-speed steels, capable of turning the hardest and most difficult of engine and carriage tyres, has definitely made the machining of these a commercial job, to the exclusion of schemes for grinding the tyres on the treads instead of turning them, a process which only the extreme difficulty of machining prior to the introduction of the new tool steels made attractive.

In the turning of tyres, the first essential is a single-point tool which serves the purpose of getting under the skin, whether the tyre being turned is an old one, with a hardened tread, or a new one, with the tread rolled, but black and scaled. Tools of this kind can, if desired, be obtained in the butt-welded form, i.e., with a solid piece of super high-speed steel welded on to a manganese chrome steel shank; but the usual practice is to employ a solid tool. This is because of the exceptionally heavy duty demanded. Form tools can then be used for finishing the profile.

In regard to the cutting speeds employed, an average, depending largely on the condition of the tyre and the cuts and feeds employed, is 12 to 30 feet a minute. Cut and feed depend on the strength of the machine. With a tool $2\frac{1}{2}$ in. $\times$ $1\frac{1}{2}$ in. section, cuts of from $\frac{3}{8}$ in. to $\frac{1}{2}$ in. depth, and feeds of from $\frac{3}{4}$ in. to $\frac{1}{2}$ in. per revolution are usual.

Incidentally, there is an ingenious method, sometimes employed in the United States, of turning railway tyres without removing the wheels. The method consists of replacing the brake blocks by cast steel tool holders, which are pressed against the tyres by the normal brake rigging, while a suitable air pressure is admitted to the brake cylinders. The engine is drawn along a straight level track, 300 feet in length, by the aid of a winding engine, control of which is effected electrically by the driver on the locomotive. Three tools are successively employed for roughing, finishing the tread, and forming the flange. The process cannot be adopted if the wheels are, to begin with, of irregular shape (i.e., not very round) or where uneven wear has caused a great deal of discrepancy between their respective diameters. In a variant of this method, six tools are employed in succession to tackle the flange alone and the outer part that hangs over the rail. This process is only employed for goods engines. The cutting speed used is about 25 feet a minute, and two men carry out the work in from six to eight hours.

Wherever there are no proper facilities available for giving to the super high-speed steels used for tyre turning the full and correct heat-treatment necessary, it is advisable to purchase butt-welded tools, which are already treated, and can be put into use at once. Such a tool should be shaped as in the sketch below, and should have only five degrees top rake.



Showing the type of tool which experience has proved to be admirable for the heavy duty demanded.

Grinding the tools used for tyre turning is an important operation, and one which, if not properly carried out, will involve great expense in spoiled and broken tools. Grinding should always be carried out dry on a free cutting wheel. The wet grinding of high-speed steel carries with it the risk that the operator will keep the tool in too long and hard a contact with the face of the wheel. This will cause local heating of certain portions of the tool being ground, usually the centre, where the water is unable to penetrate freely. When the tool is taken away from the wheel, the water at once strikes this hot place, and causes sudden cooling, which leads to the formation of a grinding or surface crack. When the tool is set to work the severe pressure and vibration resulting extend this crack until ultimately the tool fractures.

When the tools have been heated up in cutting, or have been ground dry, they should never be plunged into water for the purpose of cooling them. This causes stresses which will probably produce cracks. The modern super-high-speed steels are very dense, and severe contraction inevitably creates undesirable stresses, while in no way is cutting power increased by this drastic treatment.

A more recent development in tyre-turning tools is the button tool, which is a circular tool, with or without a stem, held in a tool holder. As soon as one portion of the cutting edge is worn, the tool is rotated so as to bring a new cutting edge into action. But there is a tendency in the most modern railway shops to turn away again from the button tool and revert to the solid tool.

One great advance of modern times is the gradual

displacement of the original vertical boring and turning mills for tyres by specially designed modern machine tools. These are stronger and are able to cut away the metal faster. This has necessitated the introduction of mechanisms capable of rigidly maintaining the tyres in position while these heavier cuts were being taken. Thus, automatic, electric, pneumatic, and hydraulic chucking mechanisms have all been employed.

For example, one tyre-boring machine has a seven-jaw universal chuck-table and the most modern type of hook clamps. The chuck jaw slides are traversed by a 5 h.p. motor. Another machine for turning tyres used in the United States turns and forms the tread with tools of full contour, the roughing tool being carried by the right hand side head and the finishing tool by the left-hand side head. Both heads have horizontal feed, which can be tripped as soon as the correct diameter is achieved. The tools are carried on vertically adjustable auxiliary slides to line them up with the tyre. Sometimes an auxiliary tool holder on the right-hand side is employed for the facing of the tyre.

One point that has been overlooked in connection with locomotive tyres is that the development of the modern super high-speeds steels, capable of turning economically the hardest worn tyre, has made it possible for railway engineers to experiment with harder tyres, a possibility previously not worth entertaining, for the reason that harder tyres would have been unmachinable. It must be remembered that the hardness of the worn tyre tread approaches 120 tons per sq. inch.

The Testing of Mine and Quarry Equipment

A New Crushing and Screening Plant at Fraser & Chalmers' Engineering Works

THE highly competitive conditions obtaining in mine and quarry practice to-day make it more and more essential that no plant shall be installed that is not thoroughly efficient and capable of trouble-free operation under the duties required. For many years Fraser and Chalmers' Engineering Works have manufactured plant and machinery for every branch of the mining and quarrying industries in all parts of the world; they have continually effected improvements in the design and construction of the various machines with the aim of combining economy of operation with simplicity of design, thus facilitating adjustments and replacements and reducing repair bills to a minimum.

Continual investigations are proceeding with a view to improving the characteristics of existing designs as well as introducing new ones (for instance, a complete ore-testing laboratory is maintained where the best treatment of any class of ore can be worked out), and the works at Erith has recently been extended by the addition of a complete test plant for crushing and screening machinery. This plant enables samples of mineral ore and stone to be reduced and sized in bulk under the same conditions as prevail in the field. As a result purchasers can see the kind of product they would obtain with their own material, and at the same time design engineers are provided with useful data for determining the size and type of unit for a given duty.

The Fraser and Chalmers crushing and screening test plant is housed in a steel building erected in a prominent position at the extreme end of the works, the railway sidings and road facilities having been specially extended to enable material to be delivered direct to the plant from the trucks.

The normal sequence of a crushing and screening test is as follows. The material is first fed to a 15 × 9 in. Blake crusher, where it is reduced to a suitable size. It is then raised by means of a 12-in. elevator of the belt-and-bucket type to a 4-ton surge bin, from which it is fed uniformly along an 18 in. × 9 ft. 6 in. "Sherwen" electro-magnetic vibrating feeder to a chute leading to a Symons crusher. The plant is designed so that a Symons crusher of either the 2 ft. or 3 ft. standard type or the 3 ft. "short-head" type may be accommodated on the same foundations (with slight alterations), and in the short period the plant has been working each of these sizes has been in operation there; indeed, tests on the smallest 20-in. Symons crusher are also quite possible.

The product from the Symons crusher is lifted by a belt-and-bucket elevator to the screening floor. Here the equipment comprises either a 3 ft. × 5 ft. "Sherwen" electro-magnetic screen, a 36—78 C.6 Robins "Gyrex" screen and a 3 ft. × 6 ft. "Symons" screen, to any of which the crushed product can be passed as required by means of suitable ducts readily controlled from the floor. The oversize from the screens can be returned by a 12-in. Robins belt conveyer running beneath them to the Symons crusher for crushing thus enabling a closed-circuit test to be carried out.

The lay-out of the equipment is designed so that any of the operations mentioned may be omitted, if desired totally-enclosed ducts being provided as alternative paths for the material. For instance, the material may be fed direct to the Symons crusher when preliminary breaking in the Blake crusher is not required, or the Symons crusher may be short-circuited when a screening test only is required; alternatively, the screens may be avoided, should the crushed material not require sizing.

A load of two or three tons of material is usually necessary to enable a complete crushing test to be carried out satisfactorily; a smaller quantity can be tested if required, but little marign will be available for tests on various settings of the equipment.

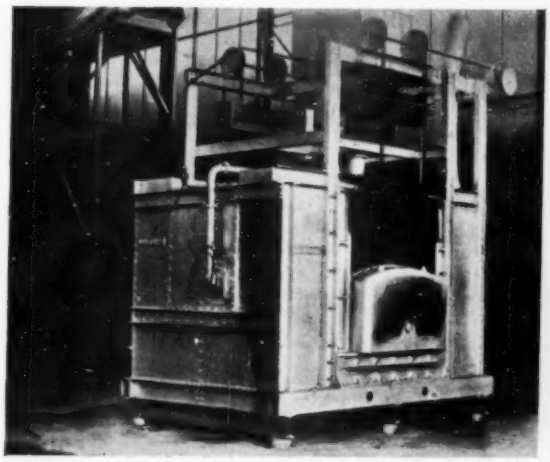
The whole of the plant in the test house is, of course, electrically operated. Individual drives through vee ropes have been standardised, and seven "Witton" d.c. motors with control gear are installed, being fed from the 500-volt d.c. works supply. The crushing plant is driven by shunt-wound motors, a 20-h.p. 1,050 r.p.m. machine being provided for the Blake crusher, and a 75-h.p. 760-r.p.m. machine for the Symons crusher; the motor for the latter is mounted on slide rails and provided with interchangeable pulleys to enable it to drive machines of various sizes. The "Gyrex" screen and the Robins conveyer and elevator are each driven by a 5-h.p. 1,000-r.p.m. compound wound motor, and the Symons screen by a 3-h.p. motor; each motor is equipped with d.c. timing starters and push-buttons. The "Sherwen" electro-magnetic feeder and screen are connected to a 380-volt three-phase 50-cycle a.c. supply, a pulsating d.c. supply for the reciprocating motion being obtained through a half-wave metal rectifier built into the vibrator.

THE Institute of Metals has issued another of its Contents List of Publications. This booklet is invaluable in helping to trace any paper published since the foundation of the Institute. An author index is also included which makes the detection of any paper a matter of only a few moments. The list is revised and brought up to date. It is available from the Secretary of the Institute, 36, Victoria Street, Westminster, London, S.W. 1, at 2s. 7d. post free.

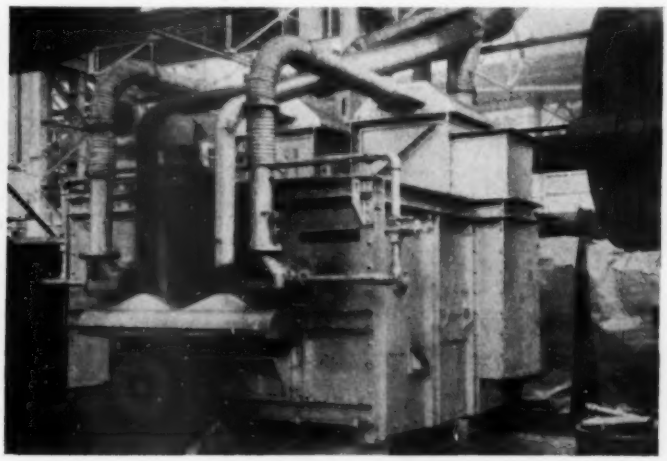
Heat-Treatment Furnaces

Two causes of low thermal efficiency are discussed which are claimed to be substantially overcome by a type of air-jacketed furnace recently developed, and which is briefly described.

IN connection with the operation of heat-treatment and forging furnaces the importance of heat storage loss is not generally realised. The ordinary type of setting is constructed of thick and heavy walls of the simple "solid" variety, stayed with iron bars, and a sprung or arched roof. Mostly furnaces of this type have to be heated up and then allowed to cool down to a considerable extent for each charge, and the result is an extremely serious loss because of the large amount of heat stored in the mass of brickwork, a greater part of which is lost during the cooling. Also another cause of low thermal efficiency is that much heat is radiated to the atmosphere, especially during the actual heating operations.



An air-jacketed oil-fired forging furnace serving two one-ton hammers



Air-jacketed gas-fired double-acting forging furnace

Further disadvantages of the ordinary solid-wall, sprung-arch setting are that the curved shape of the roof is not always on scientific lines, and allows part of the hot combustion gases to pass direct through the setting without heating the charge, while the cooling down is extremely slow. Consequently, it is sometimes necessary to resort to the barbarous practice of throwing cold water over the outside of the setting which, needless to state, plays havoc with the brickwork.

Because of these conditions, and particularly in relation to heat storage and radiation, the new "Liptak" air-jacketed heat-treatment and forging furnace constitutes a considerable advance. The basic principle consists in building the furnace of any shape or size on the suspended-wall-and-arch principle. That is standard interchangeable refractory blocks or shapes are suspended from suitable steel girders to form a flat arch or roof, whilst similar blocks are attached to a steel frame work, having the necessary vertical and horizontal sections, to form the walls. Under these conditions not much more than half the amount of refractory material is required, while each individual block is supported independently without being subjected to any cumulative loading, and can be replaced without disturbing the structure as a whole. Also the entire furnace is surrounded with an outer casing of comparatively thin insulating material, forming an air space or jacket. Through this the air for combustion, burning gaseous, liquid, or solid fuel, is passed by means of an integral, small, self-contained motor-driven fan, so that it becomes heated to about 300° F. (150° C.), whilst the roof and walls of the setting are kept cool, not over, say, 750—850° F. (400—455° C.) at the back, even with temperatures of 2,250—2,400° F. (1,230—1,315° C.) at the hot face in the furnace.

When recuperators are used the pre-heated air from the jacket is passed through resulting in a further increase in temperature from 300° F. (150° C.) to say, 500—900° F. (260—480° C.), depending upon the conditions before reaching the combustion chamber. The average nett saving obtained is about 15% of the fuel bill compared with ordinary recuperator furnace settings when the latter are in good condition.

As an example of the reasons for much higher thermal efficiency, the case can be taken of a typical solid wall and sprung-arch heat-treatment furnace, with walls of 9 in. firebrick, 3-in. insulating brick, and 4½-in. red brick (on the outside), a total thickness of 16½ in. At the inner face of the wall the temperature is, say 2,300° F. (1,260° C.) with 1,750° F. (955° C.) at the junction between the firebrick and the insulating brick, 830° F. (445° C.) at the inner face of the red brick, and 280° F. (140° C.) on the outer face, that is exposed to the air, with 2,000° F. (1,095 C.) as the mean temperature across the wall thickness, representing also conditions after long soaking.

One square foot area of this wall stores 41,250 B.th.u., and radiates 650 B.th.u. per sq. ft. per hour to the atmosphere (at 80° F.), corresponding to over 30% of the total heat supplied to the furnace lost in storage and radiation.

With the new air-jacketed furnaces the conditions are very different. The suspended refractory wall is 9 in. thick as before, but instead of another 7½ in. of brickwork, there is now a 6-in. air jacket and a 2-in. outer insulating casing. Because of the much more effective heat-insulating properties of the air layer in rapid motion, the temperature at the back of the refractory wall is now only 800° F. (425° C.), instead of 1,750° F. (955° C.), with 2,300° F. (1,260° C.), in the combustion chamber as before. As stated, the current of air on the way to the combustion

chamber is heat to about 300° F. (150° C.), and the temperature of the outer face of the thin insulating casing exposed to the air is only 160° F. (70° C.), whilst the mean temperature is 1,550° F. (845° C.), instead of 2,000° F. (1,095° C.), also representing conditions after long soaking.

In this suspended wall the heat stored is only 26,350 B.th.u. per sq. ft., that is 64% of the solid wall furnace, and the heat radiation loss 250 B.th.u. per sq. ft. per hour, or 38%, the total saving being easily 15% with recuperators in both cases. Often 50% saving is obtained with an air-jacketed recuperator-furnace setting, in which connection a special steel tube is used, as compared with an ordinary non-recuperator setting.

For these reasons the speed of cooling down, as well as heating up, is much more rapid, control of the temperature easy and efficient, and the over-all thermal efficiency is still further increased because of the flat roof, and therefore none of the dead space under a curved roof. Repairs also are carried out rapidly and easily, merely replacing one or other of the independent blocks, different from the solid wall construction, in which a considerable portion of the structure has to be rebuilt.

The Direct Photo-Electric Determination of Manganese and Chromium in Steels

IN spectrometric investigations sparks or luminous arcs are mostly used to create the spectrum, and the evaluation is carried out with the help of the photographic plate. The great difficulties and many disadvantages of this method are avoided by the direct photo-electric measurement of the intensity of spectrometric lines, first used by Tausem, Heyes and Richter for the determination of alkalis in waters.

The lines are generated by means of a compressed air-acetylene flame into which the dissolved specimen is injected by means of an atomiser. The construction of the apparatus, which is described in detail, was not easy, and many difficulties had to be overcome before a satisfactory working could be obtained. This refers especially to the atomiser and the regulation of the pressure of air and acetylene. The light of the spectral line which has to be investigated goes through the slot of the spectrometer and meets a photo-electric cell, filled with inert gas and fitted into a light-proof box. The light meeting the cell releases electrons from the very sensitive cathode, and the cathode and an electrometer connected with the cathode are more and more positively electrified. If, for each measurement, the same amount of electrification of the electrometer is taken, the photo-current is inversely proportional to the time of electrification.

Special investigations have shown that the accuracy of measurement of the whole apparatus has been sufficient, and that in concentrations of manganese up to 400 milligrammes per litre the photo-electric current is proportional to the concentration. That simplifies the investigations, for if two photo-electric currents are measured belonging to two concentrations in the range mentioned, unknown concentrations can be easily determined graphically for certain photo-electric currents.

The conclusion of the report is a detailed prescription, how to manipulate the apparatus for actual determination of manganese and chromium.

A series of analyses made by the new method are compared with ordinary chemical analyses of the same specimens, and good agreement could be ascertained. Further, it could be shown that the presence of other alloy elements does not interfere with the results of manganese and chromium.

The method is naturally not limited to steel alloys; the manganese determination can, for instance, be applied to the determination of aluminium alloys.

"Mitteilungen aus den Kaiser-Wilhelm Institut für Eisenforschung." Vol. XIX. No. 9. Gustav Thanheiser and Tosef Heyes. Price, RM.2·25.

Underground Gasification of Coal in U.S.S.R.

THE underground production of gas, involving neither coal-cutting nor raising to the surface, proposed in his time by the eminent British chemist, William Ramsay, is being practically realised in the U.S.S.R. to-day. According to Mr. D. Solovey, director of the Soviet Underground Gasification Trust, as a result of experimental work carried on for a number of years in five mines situated in the Donetz Basin, the Kuznetsk Basin, and the coal basin of the Moscow Province, considerable progress had been made by Soviet engineers in solving the problem of the underground gasification of coal.

The experiments had been carried out on coal beds of varying thickness, on different kinds of coal, ranging from anthracite to lignite, and different depths of coal seams. Various methods of gasification were tried out: gasification of coal previously crushed by mechanical means, and the gasification of coal in its natural state. Atmospheric air, or air charged with varying quantities of oxygen, was blown through coal seams underground.

Soviet engineers have designed an efficient underground gas generator and have so developed the variants of the technical process that it is now possible to produce gas suitable for different industrial purposes. For instance, the Gorlovka experimental mine produced 11,000,000 cubic metres of gas. The chemical composition of this gas was under the complete control of the experimenters. By changing the oxygen supply of the blast, they turned out either "power" gas suitable for firing boilers at electric generating stations, or "process" gas of high calorific value, suitable for manufacturing synthetic benzine and synthetic ammonia, and for the direct reduction of metals from ores without the use of the blast-furnace.

On the basis of the experiments referred to, the building has been commenced of several plants for the underground gasification of coal on a semi-industrial scale. The first of these plants, at Gorlovka, in the Donetz Basin, will be in operation at the end of the year, and the second at Lisichansk, at the end of next year. The first section of the Gorlovka plant will have a capacity of 17 megacalories per hour, the generated gas being intended for firing coke. The Lisichansk coal gasification plant, which will be of larger capacity, is intended to supply gas to chemical plants. Several other underground coal gasification plants are now being designed.

On a provisional estimate, the cost of gas produced by underground gasification methods averages half a kopek per 1,000 calories. Gas produced on the surface costs twice that amount. Mr. Solovey is of the opinion that the cost of producing gas at the underground gasification plants to be erected in the next few years will be 30 to 50% less than the present provisional estimate of half a kopek per 1,000 calories.

The Canadian Silver-mining Industry

SILVER-mining in Canada is not a distinct mining industry, as silver or silver-bearing minerals usually occur in association with other metals of economic value; with lead and zinc; with cobalt, nickel and arsenic; with lode and placer gold; in copper-gold and nickel-copper ores, and at Great Bear Lake, North-West Territories, with uranium and radium. Silver-lead zinc mining is a very important industry in British Columbia and, to a lesser extent, in the Yukon Territory.

Some years ago the mining of silver-lead-zinc ores in Eastern Canada attained a position of considerable importance in the provinces of Ontario, Quebec and Nova Scotia, and a revival in the mining of these ores has been recorded in both Quebec and Nova Scotia during 1935 and 1936. In addition to its recovery from silver-lead-zinc ores, zinc is now produced in large quantities from the copper-gold-silver ores of the Flin Flon mine.

Intercrystalline Cracking of Steel

Investigations on intercrystalline cracking of boiler steels have recently been carried out, and several new results have been obtained which throw further light on the causes of failures. These results and their explanation are given.

STATISTICAL investigation of water conditions existing in boilers suffering intercrystalline cracking, and early experimental work, indicated that failure of steel by intercrystalline cracking was primarily caused by sodium hydroxide. Further study over a period of years has led to the discovery that at 250° C. very small amounts of sodium silicate in the sodium hydroxide greatly influenced the cracking, and the tendency has existed to make the assumption that the action of sodium hydroxide-sodium silicate or very similar solutions would serve to explain the production of intercrystalline cracks under all conditions. To prove or disprove this point of view, an investigation has been conducted under a co-operative agreement between the Joint Research Committee on Boiler Feedwater Studies and the United States Bureau of Mines. The research which was carried out by W. C. Schroeder, A. A. Berk, and R. A. O'Brien* made tensile tests in sodium hydroxide solutions at 250° C.; determined intercrystalline cracking in sodium nitrate, sodium hydroxide, and nitric acid solutions; and correlated the information available on this type of failure.

The series of tests carried out at 250° C. on concentric ground tubular specimens of boiler-flange steel in sodium hydroxide-sodium silicate solutions showed the tensile strength to be reduced from 33·5 tons per sq. in. to 22·2 tons per sq. in. When either titanium oxide, germanium oxide, or antimony salts were substituted for sodium silicate, it was found that titanium oxide lowered the tensile strength almost as much as sodium silicate; antimony oxide produced failure at 29·0 tons per sq. in.; and, while germanium oxide did not produce failure of the steel, definite cracking was evident. Micro-examination indicated that these solutions, under the existing experimental conditions, produced similar cracking, which was by no means completely intercrystalline, for as soon as some grain boundaries had been penetrated, failure in the remaining sound steel tended to occur in a normal transcrystalline manner.

Tensile tests at 250° C. with sodium-nitrate solutions of concentrations varying from 34 grms. to 120 grms. per 100 grms. of water did not produce failure after 10 days. Bend tests made of 0·25 in. × 0·5 in. flat bars of cold-rolled strip steel bent around rods of various diameters up to 2·25 in., and drawn together by a bolt and nut to retain as high an elastic stress in the steel as possible were immersed in solutions containing 25, 50, and 100 grms. of sodium nitrate from different sources per 100 grms of water boiling under condensers at atmospheric pressure. No sign of cracking was apparent after three days. Additions of ferrous sulphate, uranium acetate, cerium oxide, sodium chromate, and copper sulphate to boiling concentrated sodium-nitrate solutions did not produce cracking of U-bend tests. When a trace of manganous sulphate was added, however, the first specimen cracked almost through in many places in five or six hours. Other tests showed that manganous sulphate or chloride or potassium permanganate added to concentrated sodium nitrate (50 grms. per 100 grms. of water) produced cracking not only in cold-rolled steel, but also in cold-rolled annealed and boiler-flange steel, and that it made little difference whether the surface of the cold-rolled steel was machined, left as rolled, or polished. The cracks produced by the nitrate-manganese solutions in all the steels were intercrystalline.

A bend test of cold-rolled steel bent to a short radius, and immersed for three days in a boiling nitrate-manganese solution without the ends of the test-piece being pulled together was badly cracked, not on the outside, but on the inside of the bend. The cracks were intercrystalline, and the failure of the specimen demonstrated that intercrystalline cracking can occur whether the steel is under applied external stress above the yield point or not, and that internal stress resulting from cold work or other treatment may cause rapid cracking in the complete absence of external forces.

Manganese compounds are not the only ones that will produce cracking in sodium nitrate solutions for the addition of titanium chloride to a nitrate solution produced a similar result in six days. The addition of manganese chloride to sodium hydroxide solutions did not produce cracking, but U-bend specimens cracked in seven days in sodium hydroxide solutions containing potassium permanganate, a concentration of 50 grms. of hydroxide in 100 grms. of water being necessary. When sodium nitrate was substituted for potassium permanganate intercrystalline cracking was readily produced in three to seven days. Additions of sodium silicate or manganous chloride to such solutions tended to stop cracking. In causing cracking in 50 grms. of sodium hydroxide per 100 grms. of water, the most effective sodium nitrate concentrations ranged from 0·2 to 1·0 per 100 grms. of water. Three concentrations of sodium nitrate did not produce cracking in 25 grms. of sodium hydroxide per 100 grms. of water.

Additions of other substances mainly unstable oxidising agents such as sodium peroxide, sodium persulphate and sodium nitrite to concentrated sodium hydroxide solutions did not produce cracking but a small amount of sodium chromate caused cracking. U-bend specimens were also badly cracked in one to two days when 0·2 to 1·0 grms. of lead oxide were added to 50- and 100-grm. concentrations of sodium hydroxide. Sodium hydroxide-lead oxide concentrations produced cracking almost as quickly as sodium nitrate-manganous chloride solutions and in one respect were even more damaging since they penetrated the steel in many more places during the test.

The experimental results obtained explain the production of intercrystalline cracks on the basis of a non-continuous film whereby the solution tends to form a protective film over the crystal surfaces, while it attacks the grain boundaries. This condition is most readily attained with two dissolved components, but with careful adjustment it may be possible to produce cracking with only one dissolved substance, such as sodium hydroxide or sodium nitrate, if the concentration and temperature can be adjusted to maintain some corrosive action, and yet only partially cover the surface of the steel. U-bend tests in nitric acid tend to confirm this explanation. Such tests were carried out by immersing specimens of cold-rolled steel in nitric acid concentrations of 0·2 to 0·9 grms. per 100 grms. of water at 70° to 80° C., when cracking occurred in nine to 12 days.

These new results and their explanation have the following important implications with respect to the production of intercrystalline cracks in boiler steel. First, not only

* *Metals and Alloys*, 1937, Vol. 8, No. 11, pp. 320-330.

one solution, but a variety of solutions of different compositions may promote failure. Second, since the reactions may be stopped or started by surface conditions on the steel, they will obviously be extremely sensitive to small changes. Third, since temperature and solution conditions must be quite accurately adjusted to produce cracking, it may occur only intermittently in a boiler. Fourth, some substances that are used to prevent cracking do so by changing or producing a new surface film on the steel. Fifth, the results definitely show that it is not necessary to have an applied load on the steel to produce cracking. The internal stresses resulting from cold work or other treatment will allow the solutions to attack the steel. If an applied load is present, it may, of course, hasten ultimate failure, and at the same time give cracks that are partly intercrystalline and partly trans-crystalline. Sixth, neither repeated stress or corrosion fatigue necessarily play a part in the production of this type of cracking, and although they may hasten the destruction of the metal, cracking can be produced in their entire absence.

Large Steel Forgings in Carbon and Alloy Steels

The processes involved in the production of large steel forgings were briefly described by Dr. W. H. Hatfield in a recent lecture before the Rugby Engineering Society, and considering the magnitude of these operations and the natural difficulties presented, it is remarkable that the art of metallurgy has been brought so near to being a science.

IN the manufacture of large steel forgings the feature of major importance is the slow freezing of large masses of liquid metal. The problem may be illustrated by one case in which an ingot was produced weighing 169 tons. The accurate operations required to pour so large a liquid mass into the mould is in itself a considerable achievement. When this has been done the freezing process takes many hours. Further problems are presented in the subsequent manipulation of this large mass, the magnitude being understood when it is realised that this ingot had to be reheated to yellow heat no less than 37 times. In each reheating there is oxidation and scaling involving a loss of weight in each operation.

Solidification of the ingot in the mould commences at the base and continues progressively upwards, the liquid steel at the top feeding downwards to prevent the formation of a cavity which would otherwise take place due to the contraction of the steel on freezing. The important feature is that although the steel is homogeneous when liquid, it is definitely heterogeneous when solidified. The carbon content, for example, varies from point to point throughout the ingot, as do also the proportions of the other elements, manganese, phosphorus, sulphur, etc. The steel is purer in the lower central portions that the original liquid, whereas at the top there is a large section which is less pure than the original liquid, and contains the greatest amount of segregate. If a section along the axis of the ingot is polished and etched, a series of lines or streamers can be observed along which the impurities segregate. It is important to remember that, although these lines of segregates may be practically absent in small masses of steel, they do exist in large ingots. These segregates are made up of sulphides and oxides, chiefly those of silicon, manganese and iron, and until we can entirely eliminate oxygen from the large volume of liquid steel, or devise processes to take out the sulphur, we shall inevitably have these streamers.

A great deal of research work is being carried out on this problem, and an investigation is being undertaken, in conjunction with the British Thomson-Houston Co., on a 60-ton rotor shaft. Careful experiments are being carried out on the strength of the rotor in all directions, and hundreds of test-pieces have been examined. This work is still in progress, and will be published in due course.

It must be taken as axiomatic that steel is heterogeneous, and when making use of a piece of steel, the engineer must take into consideration the general layout of the heterogeneity after forging. In the forging operation, the first stage is the reheating of the ingot, and the chief difficulty here is to obtain a uniform temperature throughout the mass. To obtain data on this subject a 30-ton ingot had a hole drilled down the centre, and thermo-couples were applied at various points along the axis, on its surface and in the furnace itself. Curves were plotted showing the rise of temperature at different points with time. After six hours, although the temperature in the furnace approached 1,350° C., it was only about 500° C., in the centre of the ingot, and it took 20 hours for the whole of the inside of the forging to attain a uniform temperature of approximately 1,200° C.

This experiment, together with others, has put the art of reheating of ingots on a more scientific basis, and it is now known what time will be required to bring different masses to a reasonably uniform forging temperature.

The effects of the size of the ingot may be seen from an examination of the micro-structure. It is observed that with small bars it is relatively easy to get a fine micro-structure, but with a 50-ton forging the structure is very much coarser because of the very much slower rate of cooling. The rate of cooling is dependent in large masses upon the thermal conductivity of steel, and cannot, therefore be accelerated. It is this slow cooling which fixes the limitation on mechanical properties. In dealing with large masses, we are at its mercy, except in so far as we can circumvent it by artificial means. In order to add strength under these conditions, elements are added which will alloy with the steel, for example, nickel, chromium and/or molybdenum. These additions fundamentally modify the physico-chemical changes taking place during cooling down, and permit meta-stable conditions to exist at normal temperatures. By this means, steels can be obtained which will stand high stress, and such steels have very different micro-structures from that of plain carbon steel.

Two important features which need to be considered in the use of steel are: the changes in properties occurring during the life of the apparatus, for example, over a service period of 15 or 20 years, and the properties of the steel, not at the manufacturer's works, but at the operating temperatures on site when in use. On the first point, there is at present very little information available, partly because very few accurate tests were taken on material used in machines installed 20 years ago. It is known, however, that certain steels do undergo changes with passage of time at high temperatures. A long-time series of experiments is in progress on this subject, and certain tests have been going on now for over 8½ years. It will naturally take a considerable time to get all the accumulated data required, but the work is of very great importance.

In conclusion, considering the magnitude of the operations that have to be performed and the natural difficulties presented by the physico-chemical processes involved, we may consider it amazing that it has been possible to bring the art of metallurgy so near to a science as it is.

Business Notes and News

North-East Coast Engineers open Branch at Sunderland

A branch of the N.E. Coast Institution of Engineers and Shipbuilders has been inaugurated in Sunderland. It has, however, been realised that it would be more convenient to Sunderland members if meetings could be held in Sunderland as well as in Newcastle, and for the remainder of the 1937-8 Institution session such meetings will be held.

The chairman of the Branch is Major R. N. Thompson; the honorary secretary is Mr. Allan J. Marr, and the representative committee consists of Messrs. R. A. Bartram, A. J. Berry, F. W. Dugdale, J. Ramsay Gebbie, K. O. Keller, R. G. Thompson, Principal E. R. Verity, and Mr. H. W. Wilcox.

At the inaugural meeting, Dr. G. S. Baker repeated his Andrew Laing lecture of last November, the title of which was "Development of hull form of merchant vessels."

W. H. Dorman: Capital Reconstruction

Some opposition has been voiced against the proposal to reduce to 6% the interest on the 10% Second Mortgage Debenture stock of W. H. Dorman and Co., Ltd., builders of petrol and Diesel engines. The company aim at reconstruction of capital so as to be in a position to distribute future profits by way of dividends. No dividends have been paid since 1919-20.

It is proposed to reduce the issued capital from £323,750 to £169,250 by reduction of the nominal value of the 250,000 5½% Non-cumulative Preference shares of £1 to 10/- each, and by writing down the 295,000 Ordinary shares of 5/- to 2/- each, and to reduce the note-conversion reserve by £298. Compensation for the reduction in value of the Preference shares will be made by increasing the rate of interest from 5½ to 11%.

Activity at the Sydney Plants of the Dominion Steel and Coal Corporation Limited

The Sydney (Nova Scotia) steel plant of the Dominion Steel and Coal Corporation, Ltd., are now running at more than rated capacity, and will continue to do so for some time. Coal-mining operations are on a capacity basis, and will continue thus throughout the winter months, if weather conditions permit. Iron-ore shipments for 1937 will aggregate 1,700,000 tons, the highest total for several years.

The Sydney steel mills are busily engaged on domestic and export business, and have apparently not suffered from the "back-wash" of conditions in the United States. Exports to Great Britain are expected to continue until 1940, and one-third of the Sydney steel capacity is scheduled for the English market each year for the next three years. Should domestic business fall off to any appreciable extent, it is understood that exports to England could be "stepped-up" under this contract in order to take up the slack.

The New "Mauretania"

The new Cunard-White Star liner, *Mauretania*, is making good progress, with six decks completed and the promenade deck well in hand. Some 2,000 men are working hard, and it is expected that her maiden Atlantic voyage will take place in about a year-and-a-half's time. This will be the biggest passenger vessel to be built in an English shipyard. Neither launching nor sailing dates have yet been decided, but some 500 bookings for the maiden voyage have already been received. July has been suggested as the launching date.

Cammell, Laird and Co., Ltd., have plenty of other work to keep their Birkenhead shipyards busy, and it is probable that the eleven vessels now under construction there will be launched this year. The other ten vessels are: four warships (three submarines and one cruiser), the battleship, *Prince of Wales*, which will probably be launched in December, two Ellerman cargo liners, two passenger and cargo steamers for John Holt and Co. (Liverpool), Ltd., and a motor tanker.

If this company can launch all eleven vessels during the year they will achieve their highest record annual tonnage. In spite of this activity, it is confidently expected that the company will receive further orders during the year.

Barytes Discovered in North-East England

In the report published by the Technical Advisory Committee of the North-east Development Board, Professor Granville Poole (Professor of Mining at King's College, Newcastle) states that mineral deposits in Upper Teesdale and Weardale include large quantities of barytes, lead and fluorspar. The largest exposure is a vein at Closehouse of about two-and-a-half miles length, and possibly containing hundreds of thousands of tons of barytes of excellent quality. Three or four barytes are being worked.

Barytes are valuable in the preparation of barium compounds, and in the manufacture of gramophone records, paints, and some types of paper and cloth.

Canadian Mineral Production, 1937

The production by Canadian mines in 1937 is estimated to have reached an aggregate value of $452,054,000, an increase of 25 per cent. as compared with the 1936 total. Gains are reported in all groups, but the greatest increase is in the metals division, output being valued at $333,088,000, a gain of 28 per cent. The production of metals, in fact, was greater than the total for all minerals in any year except 1936. There was a record production of gold, copper, lead, zinc, nickel, platinum metals, selenium, tellurium, crude petroleum, asbestos, sulphur, nephelin-syenite, and salt.

Chemists in Industry

A notable innovation in the world of learned societies was recently announced by the Society of Chemical Industry. It is stated that as there are so many specialised sections of applied chemistry which are on the fringe of the work of the Society's subject groups, such groups are to be allowed to form panels with the object of catering for those chemists whose work is so specialised.

The first panel to be formed deals with micro-biology, as applied to all industries utilising micro-organisms—e.g., food, agriculture, dairy, leather and the fermentation industries. At the same time the panel will deal with the prevention of micro-organisms, and such subjects as the micro-biological spoilage of any raw or manufactured materials will figure in the discussions. The subjects of the panel meetings, in some cases, will have broader aspects than the merely chemical, such as, for instance, marketing, finance and advertising. Panels dealing with aspects of the activities of other groups are now in the course of formation.

Existing groups in the Society are devoted to problems concerning food, plastics, road and building materials, and chemical engineering, whilst the subjects discussed in the Society's general programme range from textiles to the oil industry.

The science of chemistry is playing an increasingly important part in modern industry, and it is felt that this innovation will allow the applied chemists' work to be utilised more fully.

The Temperature Range in Motor-Car Production

It is rarely realised that a modern car is a product both of high and low temperatures. It is a striking fact, for instance, that in one operation the normal temperature may exceed 2,500° F., while another involves working temperatures over 100° below zero. What is perhaps even more surprising is that very often high and low temperatures are required at the same detail of a car.

An interesting illustration of this is found in the manufacture and assembly of heat-resisting valve-seat inserts. The hard alloy steel used for these rings is melted in electric furnaces attaining a temperature of 3,100° F., and is poured at a temperature of 3,000° F. For their fitting in the exhaust ports of the cylinder block they pass to another extreme, and are placed in refrigerators containing liquid oxygen at a temperature of −170° F.

This very low temperature contracts the rings sufficiently to allow them to slide into recesses prepared for them in the cylinder block, and, in the Ford works, a machine of special design ensures that they are properly seated. When the inserted rings expand on regaining normal temperature, they fit so tightly that there is no danger that they will ever work loose.

Metal for the cylinder block is usually poured at a temperature of 2,580° F., while the cold testing of engines and oils is carried out in a refrigerating room, which is usually reduced to a temperature of approximately 16° F.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£81	10	0
Chinese		67	0	0
Crude		39	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11¼
Brazed Tubes	,,	0	1	1½
Rods Drawn	,,	0	0	9¼
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	5⅝

COPPER.

Standard Cash		£43	10	0
Electrolytic		48	0	0
Best Selected		46	13	0
Tough		45	10	0
Sheets		78	7	6
Wire Bars		47	18	0
Ingot Bars		47	18	0
Solid Drawn Tubes	lb.	0	1	0¼
Brazed Tubes	,,	0	1	0½

FERRO ALLOYS.

‡Tungsten Metal ° Powder nominal	lb.	£0	6	1½
‡Ferro Tungsten ° nominal	,,	0	6	0
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL: 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL: 6–8% Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon. scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	0	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	18	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	2	2	6
Durham	—	1	18	6
Furnace Coke—				
Scotland	—	2	0	0
S. Wales	—	1	17	6
Durham	—	1	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£72	0	0
*Commercial Ingots		55	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	1
*Cored Bars	,,	0	1	3

MANUFACTURED IRON.

Scotland—				
Crown Bars		£13	10	0
N.E. Coast—				
Rivets		12	15	0
Best Bars		15	15	0
Common Bars		12	10	0
Lancashire—				
Crown Bars		13	10	0
Hoops		14	2	6
Midlands—				
Crown Bars		13	10	0
Marked Bars		15	15	0
Unmarked Bars			—	
Nut and Bolt Bars		11	15	0
Gas Strip		14	2	6
S. Yorks.—				
Best Bars		15	15	0
Hoops		14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	1	1
*Cored Bars	,,	0	1	3
†Strip	,,	0	0	11½
†Sheet to 10 W.G.	,,	0	0	11½
†Wire	,,	0	1	1¼
†Rods	,,	0	1	1¾
†Tubes	,,	0	1	7
†Castings	,,	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—				
Hæmatite M/Nos.		£6	13	0
Foundry No. 1		6	0	6
,, No. 3		5	18	0
N.E. Coast—				
Hæmatite No. 1		6	13	0
Foundry No. 1		5	11	6
,, No. 3		5	9	0
,, No. 4		5	8	0
Silicon Iron			—	
Forge		5	8	0
Midlands—				
N. Staffs. Forge No. 4		5	8	0
,, Foundry No. 3		5	11	0
Northants—				
Foundry No. 1		5	11	6
Forge No. 4		5	5	6
Foundry No. 3		5	8	6
Derbyshire Forge		5	10	0
,, Foundry No. 1		5	14	0
,, Foundry No. 3		5	11	0
West Coast Hæmatite		7	4	8
East ,, ,,		7	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.
Per English ton — Kr.185

Billets, single welded, over 0·45 Carbon.
Per metric ton — Kr.335-385
Per English ton — £17 11 3/£20 3 9

Wire Rods, over 0·45 Carbon.
Per metric ton — Kr.385-415
Per English ton — £20 3 9/£21 15 0

Rolled Martin Iron, basis price.
Per metric ton — Kr.290-310
Per English ton — £15 4 0/£16 5 0

Rolled charcoal iron, finished bars, basis price.
Per metric ton — Kr.360
Per English ton — £18 17 6
f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean		£31	0	0
,, Braziery		27	0	0
,, Wire			—	
Brass		21	10	0
Gun Metal		31	0	0
Zinc		8	10	0
Aluminium Cuttings		71	0	0
Lead		13	10	0
Heavy Steel—				
S. Wales		3	10	0
Scotland		3	6	0
Cleveland		3	7	0
Cast Iron—				
Midlands		3	5	0
S. Wales		3	10	0
Cleveland		4	2	6
Steel Turnings—				
Cleveland		2	12	6
Midlands		2	5	0
Cast Iron Borings—				
Cleveland			—	
Scotland		2	2	6

SPELTER.

G.O.B. Official			—	
Hard		£12	0	0
English		17	0	0
India		15	10	0
Re-melted		12	10	0

STEEL.

Ship, Bridge, and Tank Plates. Scotland		£11	10	0
North-East Coast		11	10	0
Midlands		11	10	0
Boiler Plates (Land) Scotland		12	0	0
,, ,, (Marine) ,,			—	
,, ,, (Land), N.E.Coast		12	0	0
,, ,, (Marine) ,,			—	
Angles, Scotland		11	0	6
,, North-East Coast		11	0	6
,, Midlands		11	0	6
Joists		11	6	0
Heavy Rails		10	2	6
Fishplates		14	2	6
Light Rails		10	7	6
Sheffield—				
Siemens Acid Billets		11	15	0
Hard Basic .. £6 17 6 to		10	2	6
Medium Basic, £6 12 6 and		10	0	0
Soft Basic		8	15	0
Hoops		11	15	0
Manchester Hoops		11	5	0
Scotland, Sheets 24 B.G.		15	15	0

* HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	10
Finished Bars 18% Tungsten	,,	0	5	0
Extras:				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to ⅛ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ¼ in.	,,	0	0	3
,, ,, ½ in. × ¼ in.	,,	0	1	0

TIN.

Standard Cash		£187	7	6
English		187	7	6
Australian			—	
Eastern		188	15	0
Tin Plates I.C. 20 × 14 box		1	2	6

ZINC.

English Sheets		£29	10	0
Rods		23	0	0
Battery Plates			—	
Boiler Plates			—	

LEAD.

Soft Foreign		£17	7	6
English		19	10	0

* McKechnie Brothers, Ltd., Jan. 11. † C. Clifford & Son, Ltd., Jan. 11. ‡ Murex Limited, Jan. 11.
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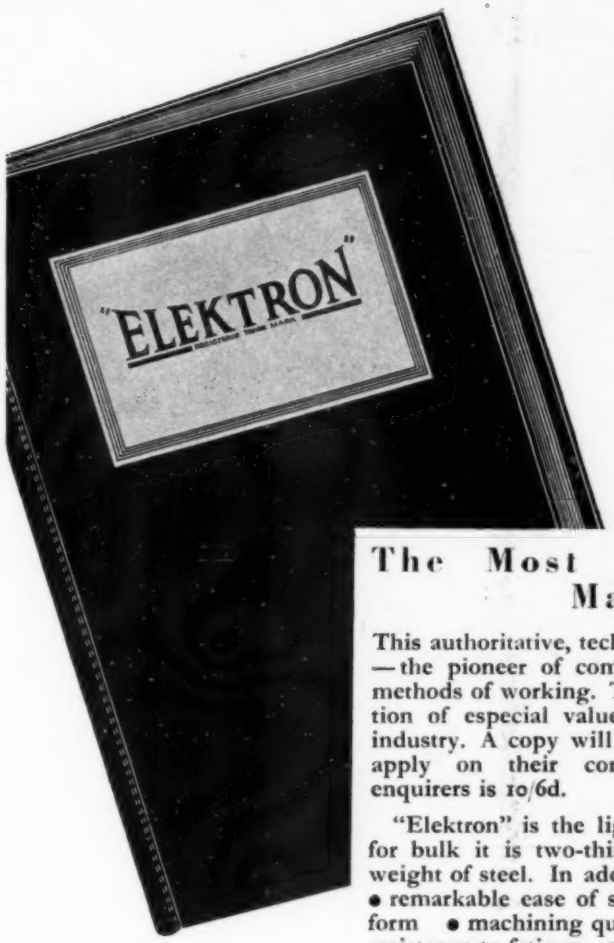

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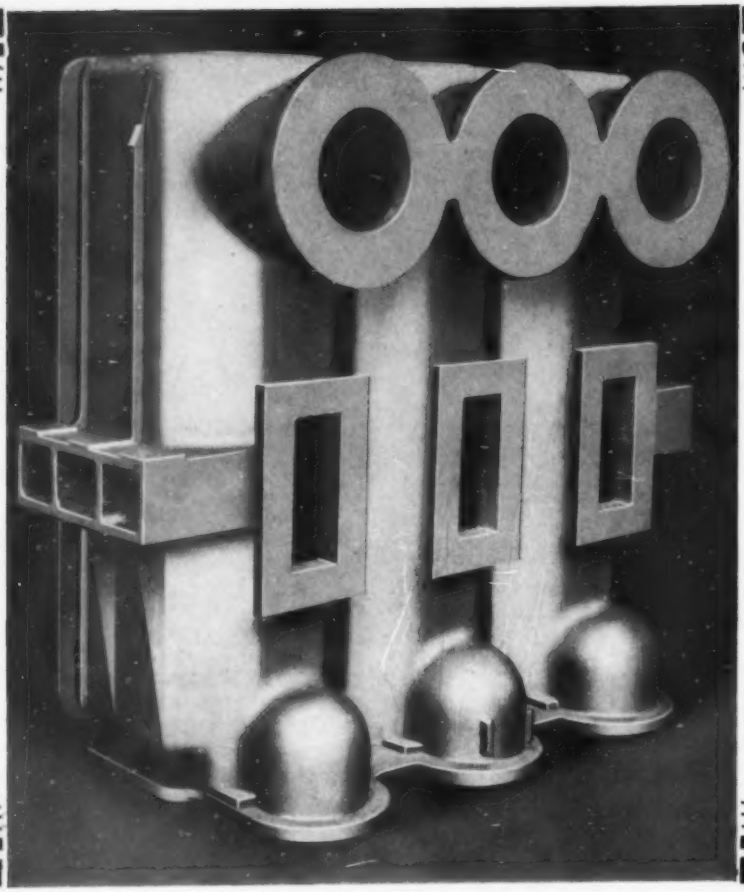

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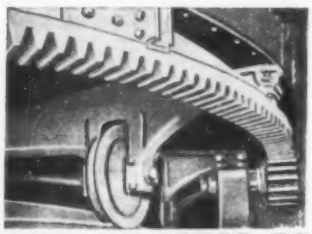

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